Manuscript Report No. 90-18

A report on the fisheries resources of the lower Nelson River and the impacts of hydroelectric development, 1988 data.

By Swanson, G.M., K.R. Kansas, and S.M. Matkowski. 1990

Manitoba
Natural Resources
Fisheries

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EXECUTIVE SUMMARY

Fisheries studies conducted on the lower Nelson River system in 1988 have followed a logical progression from studies conducted in previous years. Research began with resource inventory in 1985 and has since developed to include impact assessment and mitigation or enhancement investigations. The objectives have been to gain an understanding of the fisheries resources present, to assess current and potential impacts and to investigate enhancement or mitigative options.

In 1988, a resource inventory of McMillan and 12-Mile creeks was conducted to increase the understanding of brook trout (Salvelinus fontinalis) stocks in the Limestone River system. Both streams were found to contain habitat suitable for brook trout spawning and rearing, especially in downstream reaches. Brook trout life-stages captured or observed during this and previous studies (Gaboury 1980; Swanson et al. 1988) indicate that both streams contain self-sustaining populations.

Baseline data collection in the Conawapa Forebay portion of the Nelson River was initiated in 1988. Gill netting and drift sampling were conducted in the river mainstem to inventory fish populations and assess the importance of various habitat types to fish species. Particular emphasis was placed on lake sturgeon. Species composition was not unlike that found in the Long Spruce Reservoir in 1985 (Swanson 1986) and 1986 (Swanson and Kansas 1987), although abundances of various species differed. Few sturgeon were captured. Several were observed exhibiting spawning behaviour in the lower Limestone Rapids. Unfortunately, flow reduction from the Long Spruce Generating Station under drought conditions dewatered this area for several hours each day in June. It is believed that any eggs spawned would have been exposed resulting in their demise.

Three long-term monitoring projects were continued in 1988. Spawning brook trout populations increased slightly or remained constant since 1987 with the exception of Wilson Creek which exhibited a 50% decrease. This decrease is believed to be due to high angler harvest in Wilson Creek. The spawning area in Leslie Creek was identified in 1988. It is located immediately above the high-water level of the Limestone Forebay. Development of the forebay will negatively affect the spawning population by providing aquatic predators with easy access to the spawning site, and through lack of cover in inundated areas due to removal of trees. Numbers of larval brook trout collected by drift monitoring in Limestone Forebay and Limestone River tributaries in 1988 were similar to those of 1987. Electrofishing in Conawapa Forebay streams once more showed that juvenile brook trout were rearing in both spawning and smaller nursery streams. Spawning streams harboured more juveniles than nursery streams. The number of juveniles rearing in CN Creek was decreased by half between 1987 and 1988, and is believed to be due to effects of frozen culverts at the CN Creek road crossing. Although the culverts were installed with consideration for fish habitat, operational difficulties resulted in blockage by freezing.

Incidence of anadromy in brook trout sampled during 1988 monitoring studies was estimated at 0.7%, which is similar to that determined in previous years. Recaptures of tagged fish indicate that brook trout in the Nelson River system use habitat opportunistically, providing opportunities for mixing of stocks among streams.

A classification of four major tributaries to the Nelson River on the basis of physical and chemical characteristics was conducted in 1988 in an attempt to understand brook trout distribution patterns. The Limestone and Weir rivers support self-sustaining brook trout populations, while the Angling and Kaiskwasotasine rivers do not. It was found that physical and chemical characteristics such as temperature, pH, conductivity and alkalinity do not directly prevent establishment of brook trout populations in the Angling and Kaiskwasotasine rivers. Instead, the presence of groundwater upwellings produced by particular geological characteristics may be the parameter which allows establishment of self-sustaining populations in Nelson River tributaries.

In order to assess the importance of the Angling Lake-Angling River system to Nelson River lake sturgeon (Acipenser fulvescens) stocks, ten sturgeon were captured in Angling Lake in 1988 and tagged with 2-3-year life radio-tags. Previous studies have shown that sturgeon from the Nelson River may move into the Angling Lake system, perhaps on spawning migrations or for foraging purposes (Swanson and Kansas 1987; Swanson et al. 1988). Radio-tracking in 1988 and 1989 has shown that sturgeon use Angling Lake year-round and exhibit patterns of movement in various seasons which are similar to those observed in previous radio-telemetry studies.

One possible technique for enhancing brook trout populations in the Nelson River system is the transfer of eggs to streams where spawning does not currently occur. To investigate the feasibility of such transfer and incubation, baskets of eggs were planted at previously identified spawning areas in CN, Wilson and 9-Mile creeks in 1988. The eggs developed and hatched only in CN Creek. Physical conditions necessary for successful incubation are limited and appear to depend upon adequate upwelling groundwater.

The potential for rehabilitation of the Kettle River brook trout population was again investigated through transfer of adults from other rivers. In 1988 adults were transferred and radio-tagged in late spring to avoid complications encountered in 1987 when trout in spawning condition were transferred. The 1988 fish remained in the Kettle River-Long Spruce system throughout the transmitting life of the radio-tags and appear to have found suitable summer and winter habitat.

ACKNOWLEDGEMENTS

This study would not have been possible without the funding and support of Manitoba Hydro. Manitoba Hydro provided accomodation and storage facilities for Fisheries Branch field staff at the Limestone construction camp and the Conawapa work site. The assistance of Messrs. D. Windsor, P. Porter, W. McCaskie, B. Clelland and R. Anderson with respect to this are particularly appreciated. The authors also wish to express their gratitude to D. Cook and G. McVittie (Fisheries Branch Northeast Region), I. Hagenson and R. Janusz (Fisheries Branch Enhancement Section) for the timely availability of gear required and to C. Bradbury (Regional Services Northeast Region) for his accomodating expertise in outboard motor repairs. Thanks are also due to R. Labossiere (N.R.O. Sundance) and R. Cline (N.R.O. Gillam) for their assistance with radio telemetry flights in our absence. P. Graveline prepared brook trout fin ray samples and D. Snuggs (Energy and Mines Branch) provided the analysis along with general guidance.

Special thanks are due to Messrs. P. Graveline, R. Weaver, G. McMaster, D. Remnant, J. Stepaniuk, R. Pshebnicki, K. Martinussen, R. Caan and T. Spence for their assistance in the gathering of biological data.

The authors gratefully acknowledge the assistance of Dr. J. O'Connor throughout the study and in editorial comments provided in the preparation of this report. Typing by Ms. J. Forte is appreciated.

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PART I

MCMILLAN AND 12-MILE CREEKS INVENTORY

PART I

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INTRODUCTION

Brook trout distribution in Limestone River tributaries upstream of 9-Mile Creek, and the life stages which utilize this area, are largely unknown. Fisheries Branch studies in the mid to late 1970's were cursory in nature, indicating only that brook trout were present in 12-Mile and McMillan creeks. More recently, abundance of brook trout adults and fry in 12-Mile Creek has been studied as part of a long term monitoring program to assess the impacts of hydroelectric development in the area (Swanson et al. 1988). These studies indicated that spawning brook trout use 12-Mile Creek in similar manner to other spawning tributaries (eg. 9-Mile and Sky Pilot creeks). In 1987 thermal image sensing was also conducted on 12-Mile and McMillan creeks to identify areas with frequent coldwater upwellings (i.e. groundwater) which may be important for egg incubation (Swanson et al. 1988).

Further studies were undertaken in 1988 to classify brook trout habitat and identify life stages present in 12-Mile and McMillan creeks. The studies were conducted in areas containing frequent coldwater upwellings as well as those with few coldwater upwellings.

METHODS

McMillan Creek was sampled during the period of July 14 to 25, 1988 and 12-Mile Creek was sampled from August 4 to 14, 1988. Fish sampling was conducted using 5.1 cm and 7.6 cm stretch measure gillnets and angling in deep stretches of each stream. A backpack electrofisher (Coffelt Manufacturing Model BP-4) and angling were used in shallow riffle-pool areas. In general, downstream reaches of each creek could be electrofished while upstream reaches could only be netted and angled.

Groundwater upwelling was assessed in each stream using the infra red thermal imagery collected in 1987 (Swanson et al. 1988). Those areas with a minimum of five coldwater upwellings per kilometre were classified into a "frequent coldwater upwelling" category and those with fewer than five identified sites per kilometre were classified as "infrequent" (Figure 1).

Electrofishing was conducted in 100 m long Habitat Sections (Figure 1). Each section was divided into 10 m (thalweg length) subsections. Stream habitat parameters were mapped as per Swanson and Kansas (1987). In addition water conductivity was measured using a Hanna Instruments Model HI8033 conductivity meter, and groundwater upwellings were identified using a Fluke Model 51 electronic thermometer and a 28 inch K-type thermocouple encased in stainless steel. Groundwater upwellings were identified as those sites where a significant drop in temperature (to the annual average temperature or lower) was recorded when the thermocouple was inserted into the streambed. Three of five 100 m long Habitat

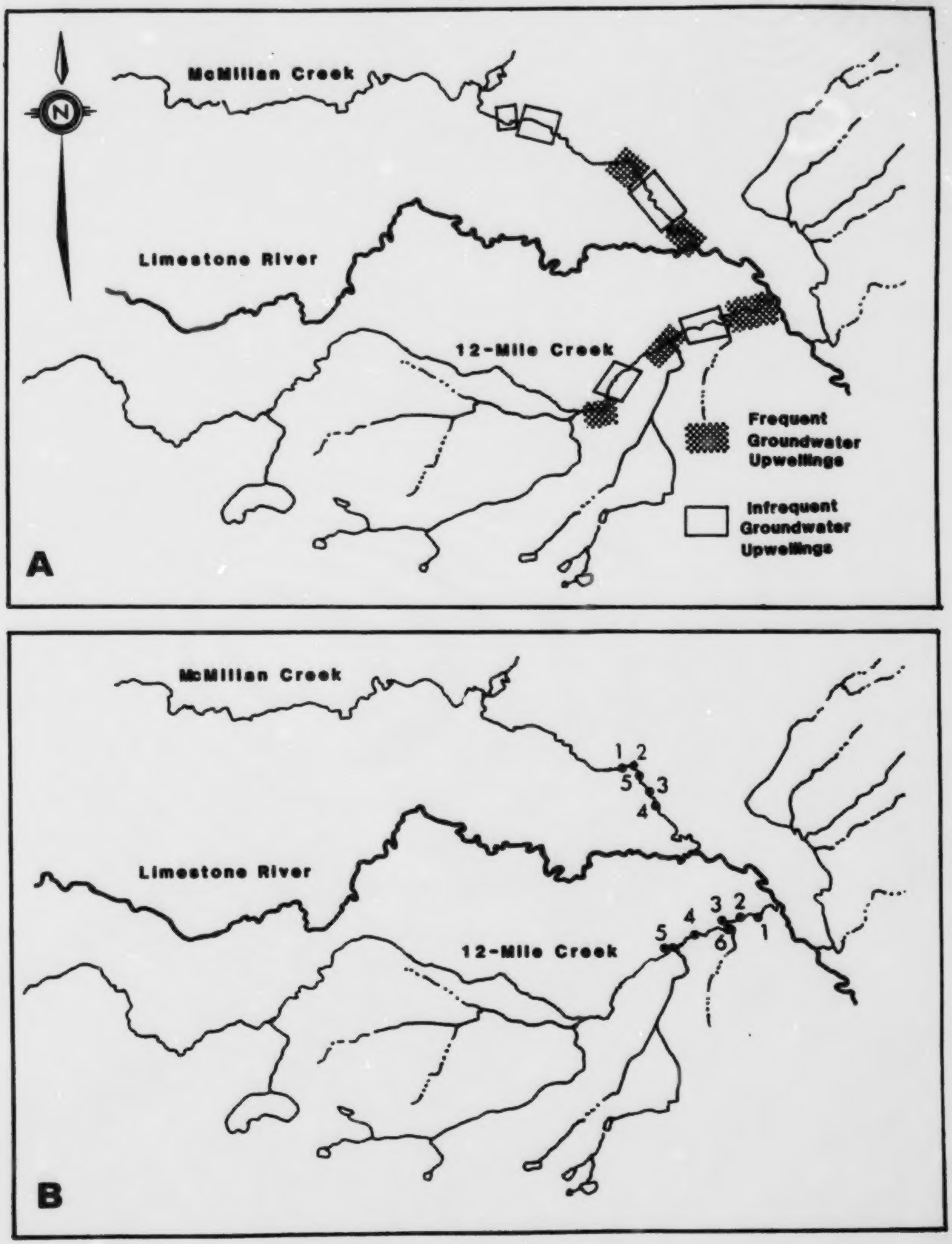
N
McMillan Creek
Limestone River
12-Mile Creek
Frequent Groundwater Upwellings
Infrequent Groundwater Upwellings
A
McMillan Creek
1
2
5
3
4
Limestone River
5
4
3
2
6
1
12-Mile Creek
B

Fig. 1. Locations of: A) Frequent and infrequent groundwater upwellings and B) 100 m habitat sections on McMillan and 12-Mile creeks.

Sections on McMillan Creek and four of six Habitat Sections on 12-Mile Creek were classified into the frequent coldwater upwelling category.

RESULTS

Habitat parameters measured in McMillan and 12-Mile creeks are presented in Table 1.

Gillnetting and angling upstream of the Habitat Sections on McMillan Creek did not yield any brook trout. In general, the habitat consisted of deep, fast flowing slough with no discernible riffle:pool sequences. Gillnetting was difficult in this habitat and electrofishing was impossible. Where the habitat was segmented into riffle:pool sequences the water was shallower and more easily electrofished. In these Habitat Sections both adult and young of the year brook trout were sampled (Figure 2). Only two adult trout were sampled in McMillan Creek, however, several others were observed following lures or partially caught in small-mesh gillnets. Juvenile trout were also observed in shallow areas of the stream but were not captured. A total of three young of the year trout were captured in Habitat Sections One and Three in McMillan Creek (Figure 1). It is notable that Habitat Section One contained a coldwater upwelling located within its length and Habitat Section Three was located just downstream of a small coldwater tributary to McMillan Creek.

Young of the year brook trout were not found in 12-Mile Creek despite the presence of coldwater upwellings in Habitat Sections One and Three. In total five adult brook trout were sampled, three of which were recaptures from activities in previous years. Again no juveniles were sampled.

Table 1. Habitat characteristics of McMillan and 12-Mile creeks, summer, 1988.

		Section	Substrate (%)[a]						Habitat (%)			Cover (%)[b]		Channel	Mean
Stream	Section	Length (m)	bld	cb	gr	sd	fn	dt	pool	riffle	glide	inst.	can.	Width (m)	Depth (m)
McMillan Creek	1	100	14.5	60.5	19.5	5.0	0.0	0.5	6.0	57.0	37.0	1.6	2.7	13.2	0.53
	2	100	0.1	54.3	29.5	13.8	0.5	2.5	39.5	0.5	60.0	4.7	1.1	13.3	0.76
	3	100	7.7	53.8	30.6	5.5	1.0	1.4	6.5	13.0	80.5	1.1	1.9	14.2	0.67
	4	100	16.0	58.5	22.0	2.5	0.0	1.0	11.0	42.0	47.0	4.2	1.7	16.0	0.43
	5	100	10.5	68.0	16.5	6.0	0.0	0.0	3.0	8.5	88.5	0.4	6.0	12.6	0.89
12-Mile Creek	1	100	7.5	59.5	32.5	0.5	0.0	0.0	4.5	26.5	69.0	0.5	2.2	16.2	0.55
	2	60	10.0	85.0	5.0	0.0	0.0	0.0	8.3	33.3	58.3	0.7	1.7	29.8	0.38
	3	100	11.5	60.5	11.5	10.0	5.5	0.0	6.0	15.0	79.0	1.1	2.1	26.7	0.71
	4	100	15.0	41.5	30.5	9.5	3.5	0.0	6.0	8.5	85.5	7.2	1.6	11.5	0.59
	5	70	17.1	63.6	10.0	5.7	3.6	0.0	5.7	15.7	78.6	2.6	4.0	12.6	0.74
	6	100	7.5	66.0	14.5	7.5	4.5	0.0	7.0	28.0	65.0	1.2	3.5	18.7	

a - bld = boulder, cb = cobble, gr = gravel, sd = sand, fn = fines, dt = detritus.

b - inst = instream, can = canopy.

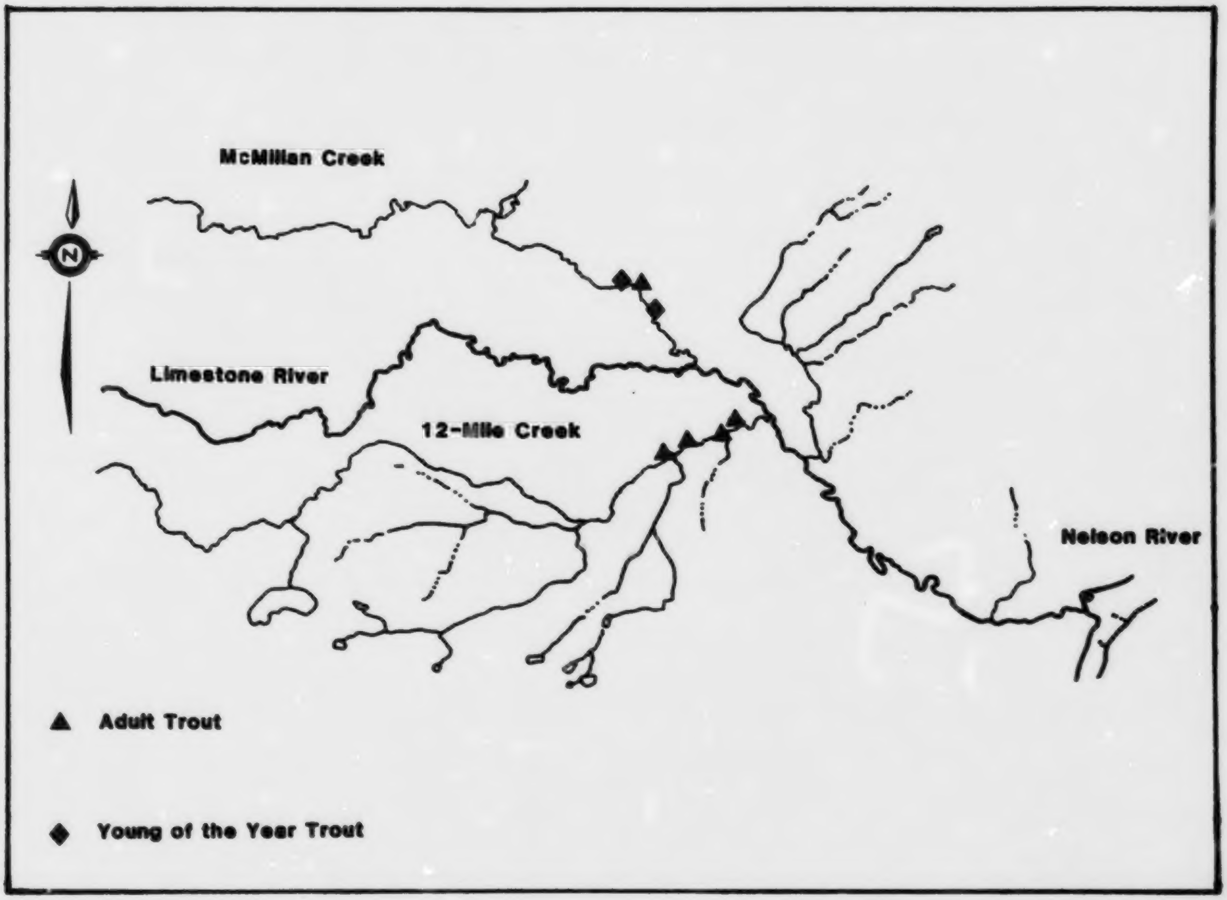
McMillan Creek
N
Limestone River
12-Mile Creek
Nelson River
▲ Adult Trout
◆ Young of the Year Trout

Fig. 2. Brook trout capture locations on McMillan and 12-Mile Creeks in 1989.

DISCUSSION

Both McMillan and 12-Mile creeks harbour reproducing brook trout populations. While no brook trout fry were sampled in 12-Mile Creek during this study, several fry were collected during drift trap studies in the spring of 1988. This information confirms the presence of brook trout spawning activity in 12-Mile Creek. While it is possible that the young of the year brook trout sampled in McMillan Creek migrated there over the course of the spring, it is most likely that their presence indicates spawning in McMillan Creek. The presence of many pike at the mouth of McMillan Creek year round (personal observations) would limit the number of young trout moving upstream into these creeks. Moreover, higher water velocities and turbidities relative to smaller creeks during spring and early summer would inhibit movement into these creeks. Finally, abundant coldwater upwellings in McMillan Creek and small coldwater tributaries flowing in provide conditions which brook trout find favourable for spawning in other Limestone River tributaries (i.e. 9-Mile and CN creeks). Since both 12-Mile and McMillan creeks harbour spawning brook trout populations they should be considered sensitive habitat.

The low densities of young of the year brook trout should not be misconstrued as an indication of minimal spawning activity or marginal trout spawning habitat. As observed at Moondance Creek and CN Creek the distribution of young of the year trout is very contagious about the area(s) were spawning occurs (Swanson et al. 1988). Density of young of the year brook trout decreased as distance from spawning site increased. Therefore, it is probable that sampling in McMillan and 12-Mile creeks did not occur at spawning sites because they are unknown at this time. It is also probable that dispersal of fry out of mainstem McMillan and 12-Mile creeks spawning areas is greater than in Moondance and CN creeks. McMillan and 12-Mile creeks are much larger and would therefore have faster flowing, and more prolonged spring spates which would disperse more fry out of the area. In addition, sampling in larger streams is more difficult which would affect sampling efficiency.

CONCLUSIONS

1. McMillan and 12-Mile creeks contain habitat suitable for brook trout spawning and rearing, including areas of frequent groundwater upwelling. Habitat is most suitable in downstream portions of each stream.

2. Brook trout captured or observed during this and previous studies indicate that both McMillan and 12-Mile creeks contain reproducing populations.

RECOMMENDATIONS

1. Efforts should be made to identify the spawning areas in each of McMillan Creek and 12-Mile creeks.

2. The size of the McMillan Creek spawning population should be estimated to assess the importance of spawning activity in McMillan Creek; no previous data exist.

3. The 12-Mile Creek spawning population should not be disturbed because it is currently part of the Limestone Generating Station monitoring program.

4. Investigations of brook trout utilization of a relatively large lake draining into McMillan Creek should take place to assess the utility of lakes to brook trout.

PART II

TRIBUTARY PHYSICAL AND CHEMICAL CHARACTERISTICS

PART II

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INTRODUCTION

Brook trout habitat is generally characterized as clear, cool, well oxygenated streams and lakes (Scott and Crossman 1979). Physical and chemical characteristics can determine which streams support self-sustaining brook trout populations and even which parts of a stream are utilized. Temperature is probably the most important physical parameter influencing brook trout habitat suitability (Power 1980). World wide distribution of brook trout is closely linked to summer temperature (MacCrimmon and Campbell 1969). The most studied chemical parameter is hydrogen ion concentration (pH). Brook trout have been known to avoid stream reaches possessing low pH values (Dunson and Martin 1973). Brook trout spawning site selection (Johnson and Webster 1977), egg hatchability (Trojnar 1977) and larval trout survival (Menendez 1976) are all influenced by the pH of stream water.

While the Limestone and Weir rivers have long been known as brook trout streams other large Nelson River tributaries have not garnered a reputation as brook trout habitat. For example, the Angling River/Angling Lake system, while long known to support walleye, northern pike and lake sturgeon, has never been known as a brook trout stream. Perhaps some physical or chemical characteristic of the Angling River/Angling Lake system inhibits brook trout utilization of this relatively large tributary of the lower Nelson River.

In an attempt to understand why brook trout utilize some large tributaries and not others a study of the physical and chemical characteristics of four large tributaries of the lower Nelson River was proposed. It was hoped that physical and/or chemical differences between well-known trout streams and those which apparently do not harbour self-sustaining brook trout populations would become evident and aid in the understanding of brook trout habitat utilization in the lower Nelson River watershed. Such information could be applied to lesser known tributaries as an aid in the identification of brook trout habitat.

METHODS

Study Streams

The study streams chosen were as follows: Limestone River, Weir River, Angling River and Kaiskwasotasine River (Figure 1). The Limestone and Weir rivers are well known trout streams while the Angling and Kaiskwasotasine rivers apparently do not contain self-sustaining trout populations.

Physical Parameters

Total drainage areas of the Limestone, Weir and Angling rivers were obtained from the Manitoba historical streamflow summary (Environment Canada 1987). The total drainage area of the Kaiskwasotasine River watershed was estimated by comparison with the other three watersheds.

Stream water temperatures were measured using a Ryan Instruments Model J 90-day thermograph. Thermographs were installed near the mouth of each river for the period of May 17 to September 30, 1988 and were checked at approximately monthly intervals. The trimean of weekly maximum temperatures was calculated as in Tukey (1977) for the period of May 20 to August 31 on all but the Weir River. Thermograph malfunction limited data available for the Weir River.

Streamflow data were obtained from Environment Canada (1987) for the Limestone, Weir and Angling rivers. No flow data were available for the Kaiskwasotasine River.

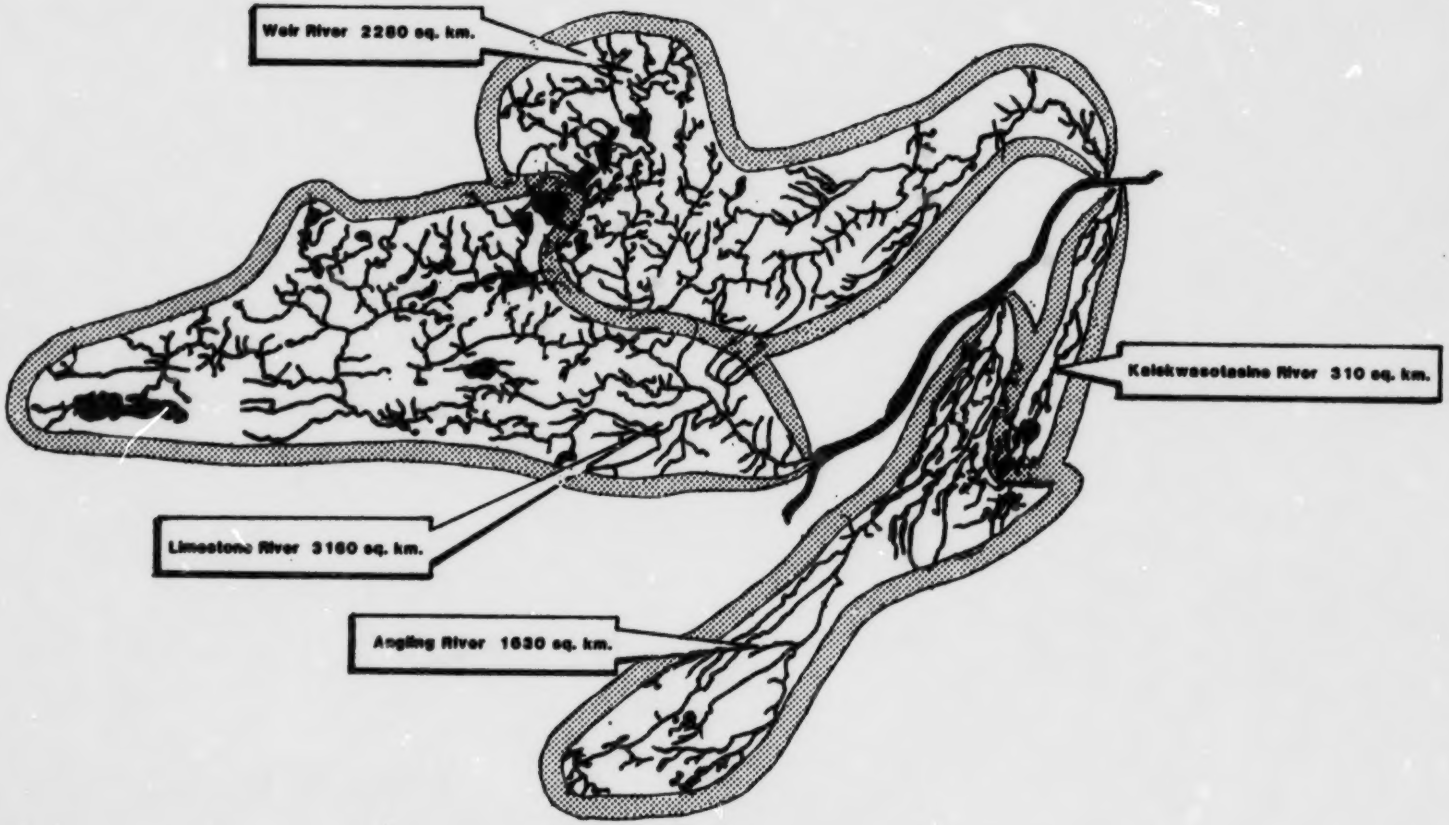
Weir River 2280 sq. km.
Kaiskwasotasine River 310 sq. km.
Limestone River 3160 sq. km.
Angling River 1630 sq. km.

Fig. 1. Drainage basins of the four study rivers. Drainage areas of Limestone, Angling and Weir rivers from Environment Canada (1987); drainage area of Kaiskwasotasine River estimated by comparison.

Chemical Parameters

Water samples were collected at the thermograph sites on three dates (two open water and one winter samples) during the period of May, 1988 to March 1989. Water samples were transported to the Technical Services Laboratory within 48 hours of collection. The parameters measured in each sample included: pH, conductivity, total alkalinity, and the eight major ions constituting salinity.

Field measurement of pH was conducted at the time of sample collection in March using a HACH colorimeter.

RESULTS

Physical Parameters

Temperature profiles for each of the four study rivers are presented in Figure 2. Gaps in temperature data are the result of thermograph malfunctions. Data are only available up to July 31 for the Weir River. The overall pattern in temperature change was similar on all four rivers. Major highs and lows occurred simultaneously. Maximum temperatures measured were 26.0°C in the Angling River and 21.1°C in both the Limestone and Kaiskwasotasine rivers. These maxima all occurred on July 28. Although temperatures are not available for the Weir River in August and September, it is likely that the July 28 temperature of 22.0°C was the maximum for the entire study period. The number of days on which the water temperature reached or exceeded 20°C was 16 for the Limestone River, 11 for the Kaiskwasotasine River and 42 for the Angling River. The trimean weekly maximum temperature (Tukey 1977) was calculated as 18.3°C for the Limestone River, 19.1°C for the Kaiskwasotasine River and 21.4°C for the Angling River.

Mean monthly discharges for the period of 1979 to 1986 are presented for the Limestone, Weir and Angling rivers in Figure 3. Figure 3 also presents discharges adjusted for drainage area.

The drainage patterns on the north and south sides of the Nelson River differ due to differences in topography. The north side of the river has greater relief and steeper stream gradients than the south side. Consequently, tributaries on the south side

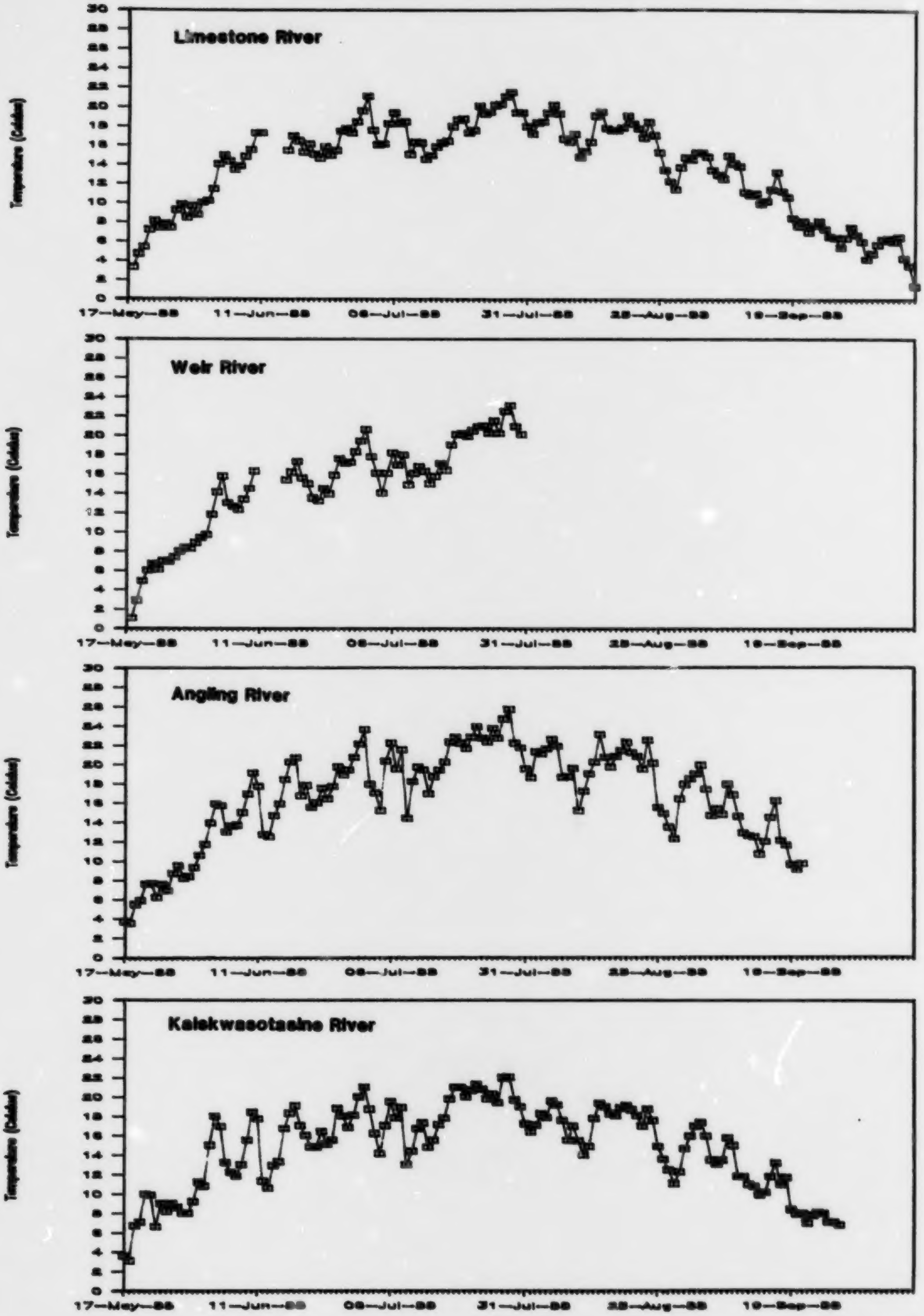

Fig. 2. Temperature profiles of the four study rivers, May to September, 1988.

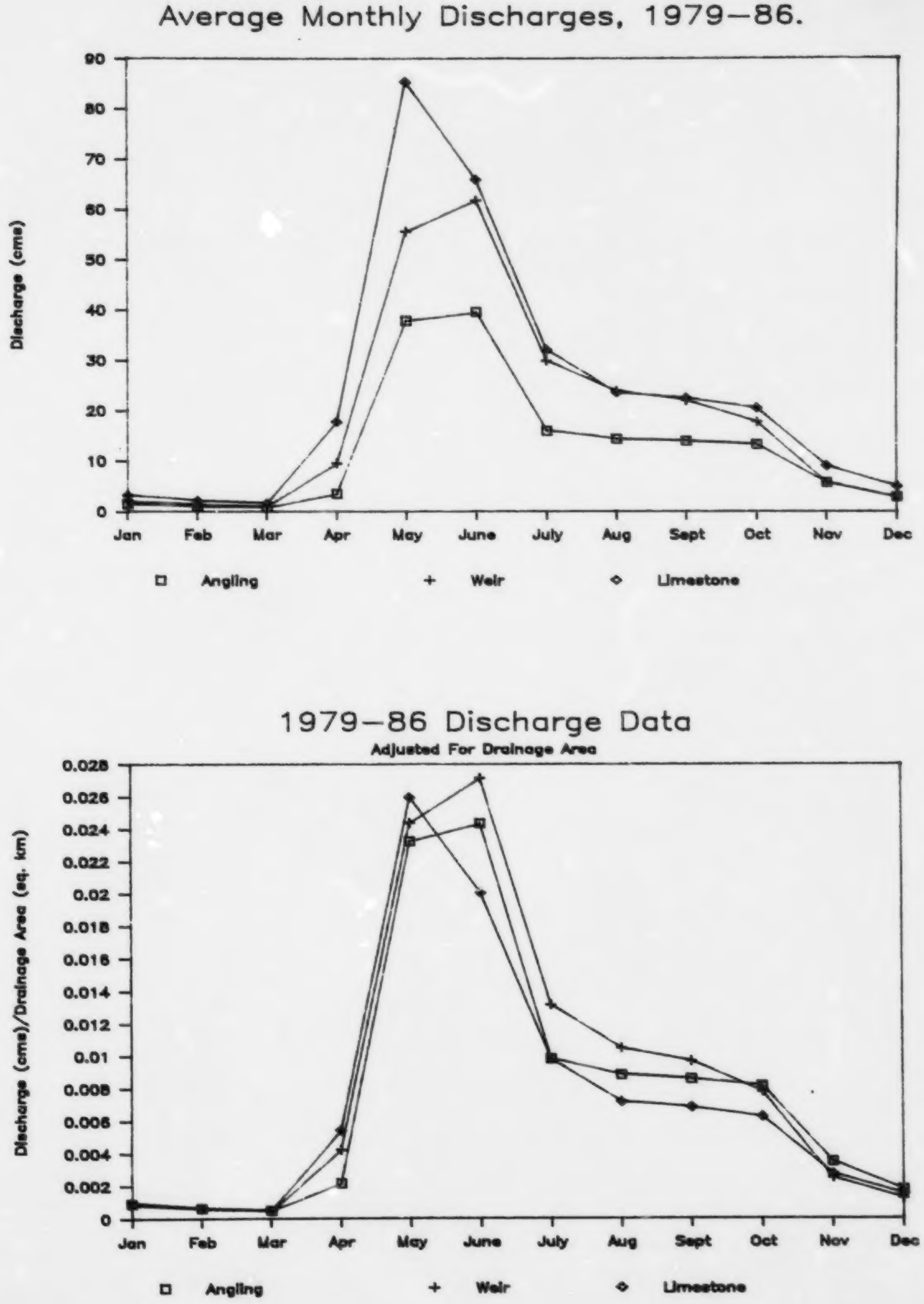

Fig. 3. Mean monthly discharges in the four study rivers for the period from 1979 to 1986 (Environment Canada 1987).

of the Nelson River drain more bog and shallow mid-basin lakes than those on the north side.

Chemical Parameters

Detailed results of chemical analyses are presented for each river in Appendix I. Data are summarized in Table 1.

All four study rivers were alkaline when sampled in May and July, and dropped in pH to near neutral or slightly acidic in March (Table 1, Figure 4). The drop in pH in the Kaiskwasotasine River was particularly marked. The range of pH among rivers was narrow in both May and July ($\leq$ 0.3 pH units) and widened substantially in winter ($\leq$ 0.75 pH units). Field pH measurements for March are consistently lower than laboratory determinations (0.2-0.25 pH units). This is likely due to inaccuracy of equipment used in the field.

In each river conductivity and total alkalinity increased in a similar pattern over the study period (Figures 5 and 6). Values were always lowest in the Angling and Kaiskwasotasine rivers. Totals of cation and anion concentrations in each sample were correspondingly lower for these two rivers (Table 1). The composition of ions was similar in all rivers: calcium and magnesium constituted the bulk of cations while bicarbonate was the most abundant anion (Figure 7). In winter the concentrations of calcium and bicarbonate increased markedly while other ions increased only slightly.

Table 1. Chemical characteristics of the four study rivers as sampled on three dates in 1988/89.

River	pH (field)	pH (lab)	Conductivity (umhos/cm)	Total Alkalinity (CaCO3 mg/l)	Total Cations (meq)	Total Anions (meq)
May 17-18/88						
Limestone	--	7.85	119	60	--	--
Weir	--	8.15	103	56	--	--
Angling	--	7.95	81.5	42	--	--
Kaiskwasotasine	--	7.90	63.3	32	--	--
July 10/88						
Limestone	--	8.15	190	100	2.58	2.12
Weir	--	8.05	145	74	2.04	1.62
Angling	--	8.20	130	66	1.54	1.42
Kaiskwasotasine	--	7.90	92.9	46	1.38	1.07
March 16/89						
Limestone	7.1	7.35	441	222	4.87	4.73
Weir	7.0	7.25	472	230	5.25	4.94
Angling	6.8	7.05	401	200	4.43	4.28
Kaiskwasotasine	6.4	6.60	304	140	3.30	3.26

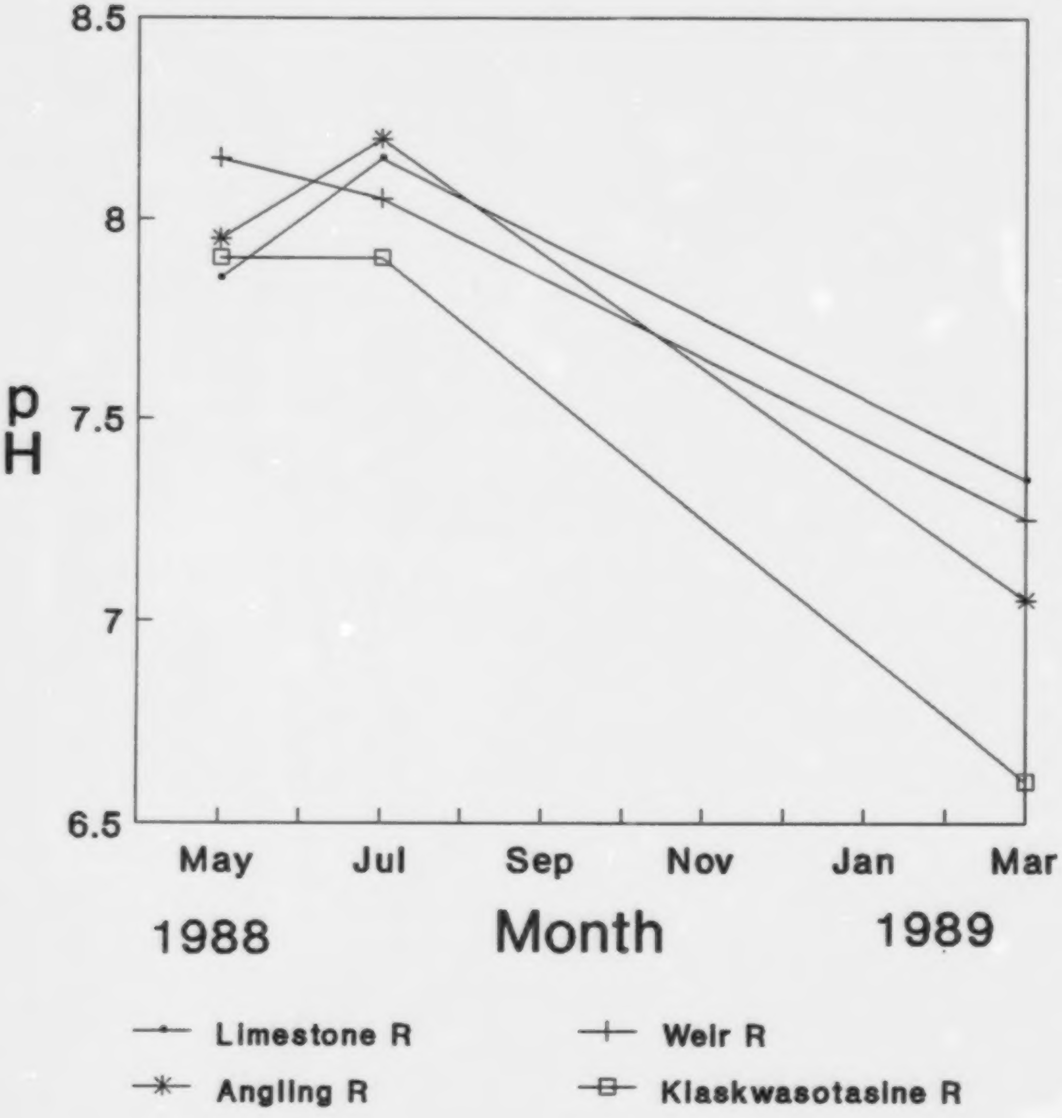

Fig. 4. Change in pH (lab measurements) over time in the four study rivers, 1988 to 1989.

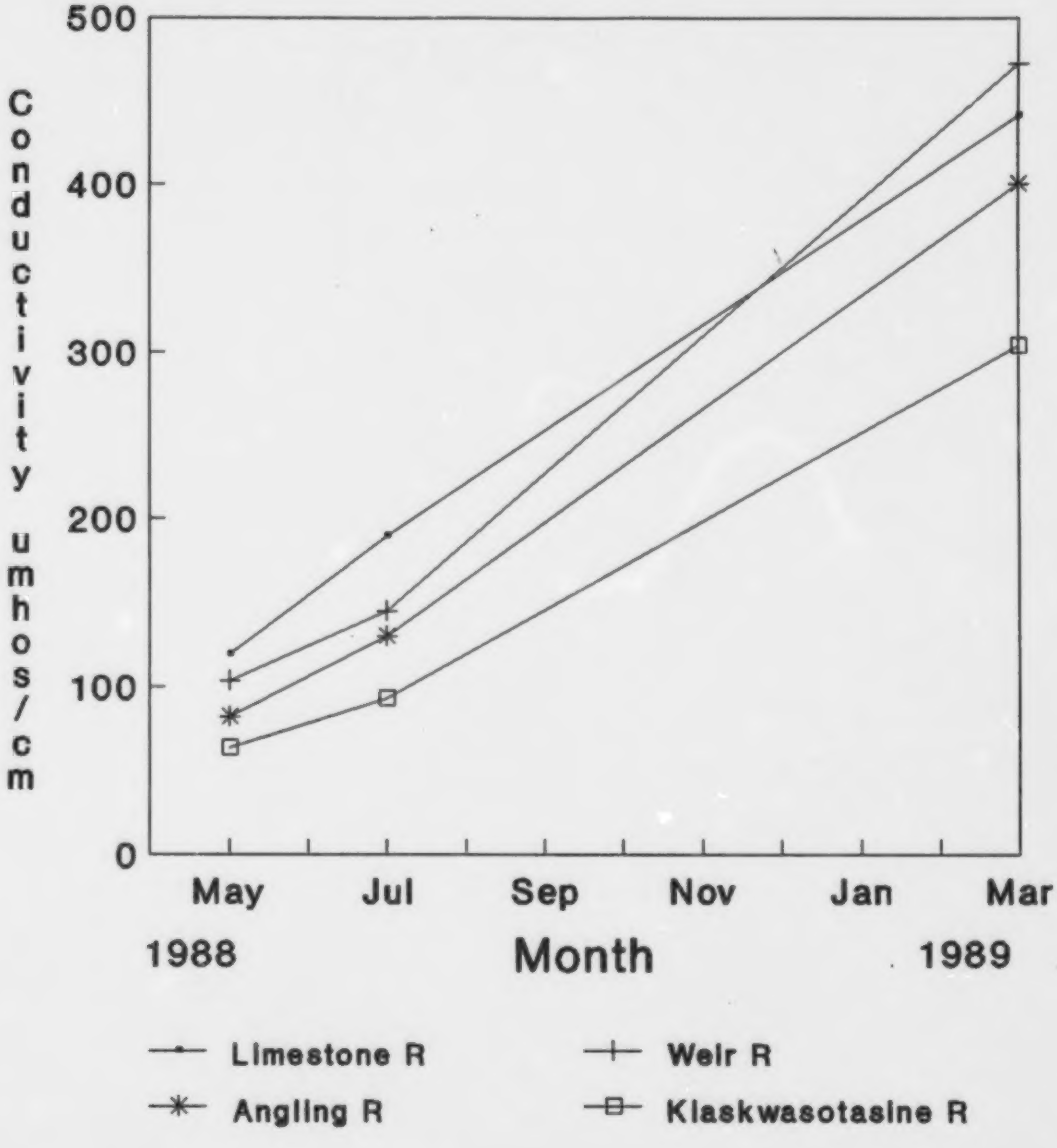

Fig. 5. Change in conductivity over time in the four study rivers, 1988 to 1989.

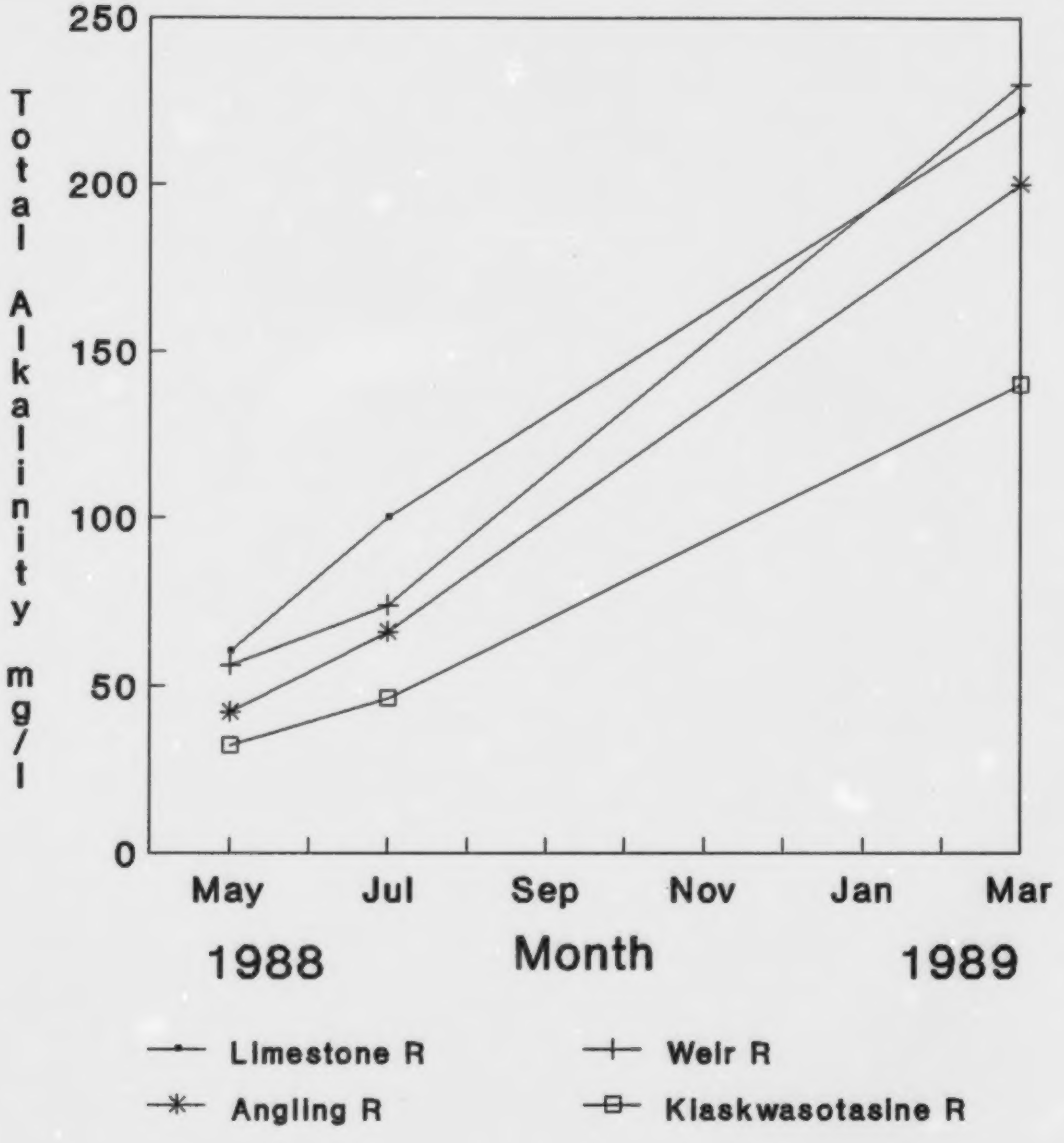

Fig. 6. Change in total alkalinity over time in the four study rivers, 1988 to 1989.

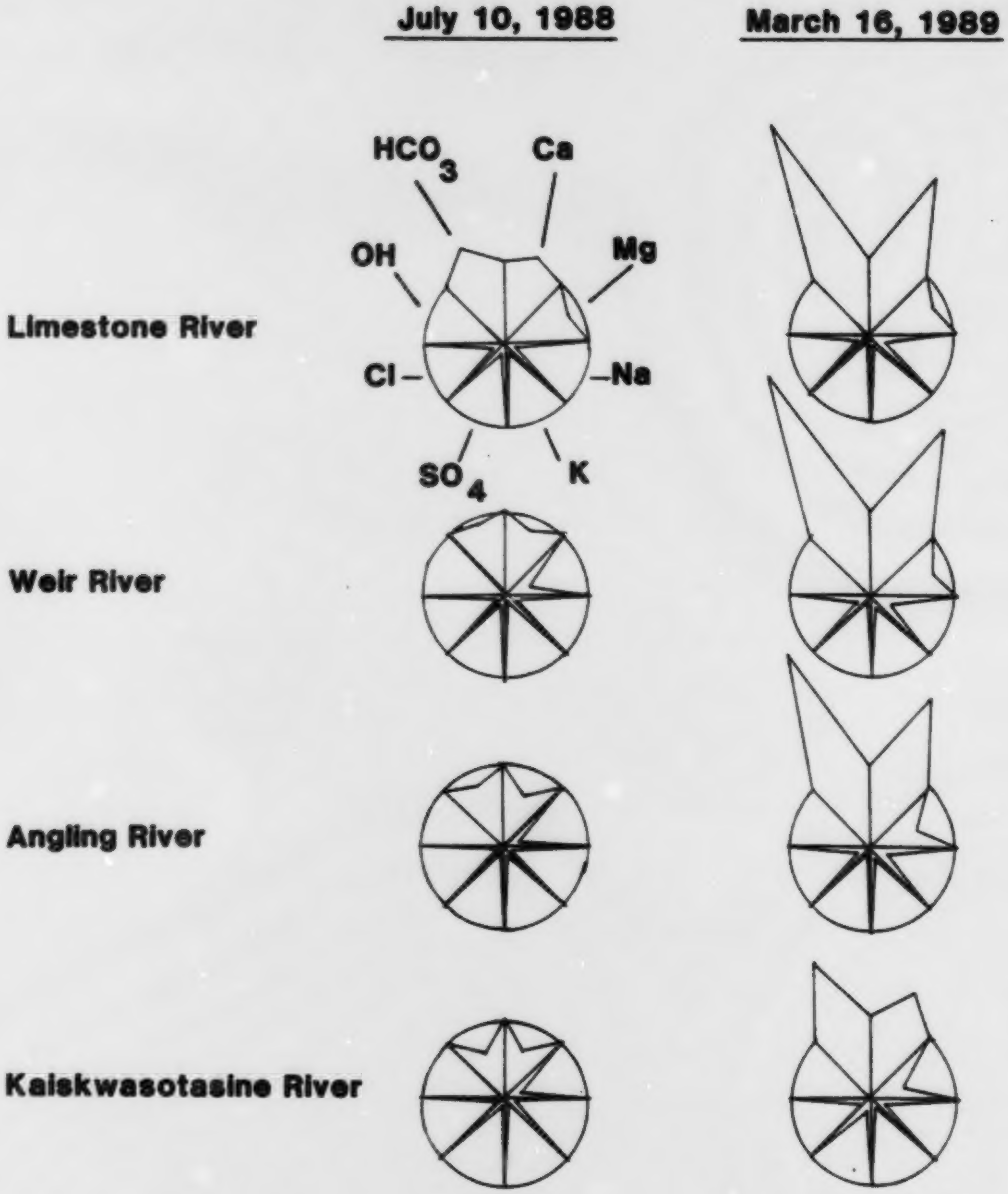

Fig. 7. Relative concentrations of anions and cations in each study river in summer, 1988 and winter, 1989.

DISCUSSION

The similar pattern of temperature change over time in all four rivers reflects influence of the same climatic conditions. The actual temperatures reached during warm periods in the pattern differ among rivers and may be important in determining brook trout distribution. Optimal temperatures for brook trout are less than 20°C although short periods (days) at higher temperatures can be tolerated (Power 1980). The maximum temperatures recorded in the study rivers were all above 20°C and notably so in the Angling River (26°C). The number of days on which water temperature exceeded 20°C was also much greater for the Angling River than for the Kaiskwasotasine or Limestone rivers. These data indicate that the Angling River is characteristically warmer than the others.

It is important to note, when considering effects on brook trout, that these temperatures represent daily maxima not constants which would have a greater effect on trout. At night, even during warmest periods, temperatures regularly decreased to near or below 20°C. It is also important to note that fish have the ability to seek refuge in areas of cooler water in a river and may avoid unsuitable temperatures when such areas are available (Power 1980).

The calculated value of trimean weekly maximum temperature has the advantage that it is not affected by a few extreme observations. It has been used to characterize streams which are suitable for trout populations. In a study of 40 southern Ontario streams all but one of those which had trimean weekly maximum temperatures less than 22°C harboured self-sustaining trout populations (Barton et al. 1985). The trimean weekly maximum temperature of the Kaiskwasotasine River (18.3°C) is well below this value and lower than that of the Limestone River (19.1°C), a well known trout river. The temperature regime of the Kaiskwasotasine River should not limit establishment of a brook trout population. The trimean weekly maximum temperature of the Angling River (21.4°C) is high but still below the 22°C limit found in southern Ontario (Barton et al. 1985). Summer temperatures in the Angling River may be near the upper tolerance limit for self-sustaining brook trout populations, but are unlikely to be the only factor preventing establishment of a brook trout population in this river.

The pattern of discharge over time is similar for the Angling, Weir and Limestone rivers. It is reasonable to assume that the same pattern applies to the Kaiskwasotasine River since it is subject to the same climatic conditions. Discharge is lowest in winter, peaks suddenly in spring, maintains a moderate level through summer and declines in fall. Low winter discharge is due to the lack of contribution by precipitation. Precipitation is stored as snow and enters suddenly upon melting in spring. Summer discharge remains higher than winter due to continued contribution by rain.

The chemical characteristics of a stream vary with discharge. The pH depends in part upon the various sources of water making up the flow. In the four study rivers these include direct surface runoff from precipitation, drainage from retention areas such as lakes and bogs, subsurface runoff from precipitation, and groundwater. Each of these sources has a characteristic pH. The percent contribution to discharge by each varies with season producing a pattern of change in pH through the year. This pattern was the same in each of the four study streams indicating similar changes in flow composition over time. In spring and summer, pH values of the rivers were very similar and all quite suitable for brook trout (Power 1980). The pH decreased in winter when precipitation no longer contributed significantly and groundwater and drainage from retention areas provided most of the flow. The change was most marked for the Angling and Kaiskwasotasine rivers which receive substantial drainage from acidic habitat such as bogs.

Brook trout have a wide pH tolerance but cannot survive in waters that are too acidic (Power 1980). Winter pH values in the Kaiskwasotasine River (6.60-lab) and in the Angling River (7.05-lab) were acceptable for juvenile and adult brook trout but marginal for earlier life stages. Embryos and alevins are most susceptible to damage from low pH. Menendez (1976) found embryo hatchability began to decrease at pH levels below 6.5 and was very poor (26%) at pH 5. Mortality of alevins increased at pH levels below 6.0.

The effects of pH on embryo development depend upon the length of exposure as well as degree of acidity. As this study measured pH only once during the period of egg development it is impossible to determine the exact extent that pH would affect embryos present in the Angling and Kaiskwasotasine rivers. It appears that the effects of pH would be slight and not likely to prevent survival of a self-sustaining brook trout population.

The composition and relative concentration of anions and cations was similar among the study rivers. The concentration of ions in water determines its conductivity. The presence of bicarbonate ions in particular determines alkalinity. The pattern of change in ion concentration over time, and therefore conductivity and alkalinity, was similar among all rivers. The higher conductivity and alkalinity in winter discharge than in summer was likely due to a greater proportion of groundwater and water which had moved through the soil. Groundwater and water which has percolated through mineral soil picks up ions (Hynes 1970). Soil in the Hudson Bay basin is calcareous (mineral) and readily leaches calcium and magnesium (Dredge 1988). The increase in conductivity and alkalinity in winter was less marked in the Angling and especially Kaiskwasotasine rivers. This difference may again be attributed to substantial drainage from bogs to these rivers. The organic surface layer in boggy areas reacts with water to remove ions (Hynes 1970). Although the study rivers differ in conductivities, alkalinities and concentrations of individual ions, none are extreme. These characteristics would not prevent establishment of brook trout populations.

The physical and chemical parameters which have been monitored in this study do not explain the absence of brook trout in the Kaiskwasotasine and Angling rivers. Based on these characteristics the two rivers appear less suitable for brook trout than the Limestone and Weir rivers but should still support self-sustaining populations.

Another physical characteristic which may explain the absence of brook trout in the Kaiskwasotasine and Angling rivers became apparent during this study. The surficial geology north and south of the Nelson River differs. The area north of the Nelson River, where most streams harbouring trout populations occur, contains deposits of primarily sand and gravel (Klassen and Netterville 1985). These deposits were formed by glaciers or glacial rivers, or as marine shorelines associated with the receding post-glacial Tyrell Sea (Klassen 1986). The area south of the Nelson River, where the Kaiskwasotasine and Angling rivers occur, contains deposits with a greater proportion of fine materials such as silt and clay deposited by prehistoric seas (Klassen and Netterville 1985). There are few deposits of coarse material.

Coarse deposits allow storage and movement of groundwater which flows out in areas of topographic lows such as valleys (Rutulis 1985). The topography on the north side of the Nelson River is steep enough to allow development of groundwater springs. The combination of surficial geology and topography on the north side of the Nelson River results in streams which characteristically contain groundwater upwellings through the substrate (Swanson et al. 1988) In the Angling and Kaiskwasotasine rivers no evidence of groundwater upwelling has been found. It is likely that the fine deposits covering the area around the Angling and Kaiskwasotasine rivers are not suited to the development of springs. Materials with small intergranular pore spaces, such as clay, have very low permeability and retard groundwater movement (Rutulis 1985; Dunne and Leopold 1978).

In the Nelson River watershed, where brook trout are at the northern edge of their range, groundwater upwellings may be critical for sustaining brook trout populations. In several other watersheds brook trout spawn at groundwater upwellings (Carline and Brynildson 1977; Carline 1980; Witzel and MacCrimmon 1983) and have been found to prefer such sites over those where no upwelling occurs (Webster and Eiriksdottir 1976). In some situations groundwater is also important for survival of underyearling brook trout (Latta 1969) and in providing suitable overwintering habitat (Raleigh 1982). Known spawning sites in streams along the Nelson River have been found exclusively at groundwater upwellings (Swanson et al. 1988). Upwelling groundwater may be necessary to prevent freezing of some streams in winter and may constantly move water past eggs providing oxygen and removing metabolic wastes. In small streams, areas where groundwater prevents freezing may provide additional overwintering habitat for other life stages of brook trout as well. Even during openwater seasons the presence of suitable habitat may depend upon groundwater. The presence of groundwater upwellings has been linked to greater use of small streams along the Nelson River as nursery habitat (Swanson et al. 1988).

If groundwater upwellings are scarce in streams on the south side of the Nelson River spawning, nursery and even overwintering habitat for brook trout may be lacking. This could preclude establishment of self-sustaining populations in the Kaiskwasotasine, Angling and other streams in this area.

CONCLUSIONS

1. Physical and chemical characteristics such as temperature, pH, conductivity and alkalinity do not directly prevent establishment of self-sustaining brook trout populations in the Angling and Kaiskwasotasine rivers.

2. Summer temperature in the Angling River and winter pH in the Kaiskwasotasine River are near limits of tolerance for some life stages of brook trout. Added stress from these factors may make trout populations more sensitive to other inadequacies in habitat.

3. Groundwater upwellings in stream beds may be necessary for self-sustaining brook trout populations in the Nelson River watershed. The apparent lack of springs in the Kaiskwasotasine and Angling rivers may prevent establishment of brook trout populations in these streams. Surficial geology may be used to help identify whether a stream is likely to contain springs and support a self-sustaining brook trout population.

PART III

BROOK TROUT SPAWNING ENHANCEMENT

PART III

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INTRODUCTION

Reproduction of brook trout populations in the Nelson River watershed appears to be limited by specific habitat conditions required for overwintering of eggs in redds. Winter conditions in spawning streams are severe and vary notably between years. During years with extremely cold winters reproductive success may decrease as fewer suitable incubation areas occur. The winter of 1986-87 was much milder than 1987-88 when some small streams froze entirely. The number of young brook trout produced in 1987 appears to have been much greater than in 1988 (results of larval drift census).

Construction activities such as stream crossings may adversely affect overwinter incubation success by augmenting freezing conditions and/or adding fine particles to the stream bed. It appears that the stream crossing constructed over Tiny Creek contributed to freezing conditions in that stream during the winter of 1987-88. The crossing at CN Creek washed out in both 1987 and 1988 adding noticable amounts of fine sediment to the stream bed.

In order to ensure continued reproductive success during ongoing hydroelectric development, and perhaps to enhance brook trout egg incubation success in undeveloped areas, the specific habitat characteristics required for overwinter incubation should be understood. This study of artificially planted brook trout eggs in three streams is an initial effort at gathering such information.

METHODS

The three streams used in this study were Wilson, 9-Mile and CN creeks. The previously identified spawning area in each stream was used as a study site, each of which occurs at an area of groundwater upwelling (Figure 1). Fertilized brook trout eggs were buried as described below, at locations where groundwater upwelling was suspected. Placement was limited by the presence of natural spawning redds and excessive water depth.

Brook trout eggs were collected and fertilized from spawners captured in the Weir River on September 24, 1988. All fertilized eggs were pooled before samples were removed. Two hundred eggs were then placed in each of eleven closed incubation baskets. The baskets, 9 cm in diameter and 10 cm high, were constructed of plastic mesh which allowed flow of water but prevented escape of eggs or fry. The bottom of each basket was lined with a layer of fine gravel followed by a layer of coarse gravel (Harris 1973). The eggs were then added and covered to the top of the basket with mixed gravel (Harris 1973). Lids were attached securely. The baskets were placed in a picnic cooler filled with water and transported by helicopter to CN Creek. They were maintained overnight in CN Creek (6.0°C) at a location just upstream of the chosen study site.

On the following morning, September 25, 1988, three baskets were moved downstream to the CN Creek study site. Three holes were dug using a shovel. Each was within 0.5 m of the others and deep enough to accomodate a basket. A steel post was embedded near the

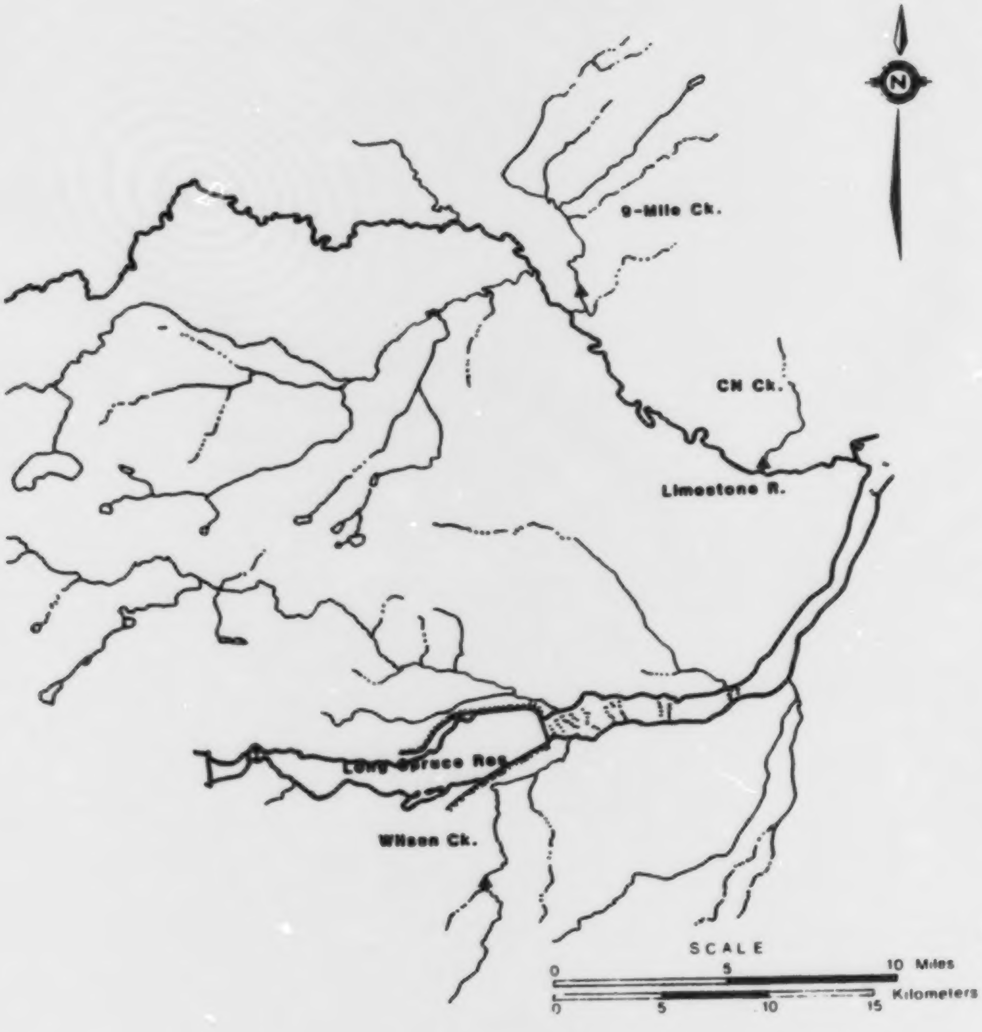
N
9-Mile Ck.
CN Ck.
Limestone R.
Long Spruce Res.
Wilson Ck.
SCALE
0
5
10 Miles
0
5
10
15
Kilometers

Figure 1. CN, Wilson and 9-Mile creeks, and the location of egg baskets in each (indicated as ▲).

holes and marked with flagging tape. One basket was placed in each hole and covered with previously removed substrate such that the lids were just below the stream-bed surface. The baskets were designated as CN1, CN2 and CN3. The stream water temperature was 6.0°C.

At 1300 hours three baskets were placed in a cooler of water and flown by helicopter from CN Creek to the study site on 9-Mile Creek. They were buried, marked as described for CN Creek and designated as 9M1, 9M2, and 9M3. Water temperature at the surface was 6.0°C.

Three baskets were similarly transported to the study site on Wilson Creek and buried by 1715 hours. Again baskets were buried within 0.5 m of each other and just under the surface of the stream bed. Water temperature at the surface of Wilson Creek was 7.5°C.

One of the two remaining egg baskets held in CN Creek upstream of the study site was removed on October 13, 1988, packed in a cooler of water and shipped as air cargo to Winnipeg. On the same day this sample was cleared with 10% acetic acid and examined by microscope to determine what percentage had been fertilized. The second sample was allowed to develop in CN Creek until October 19 and was then similarly shipped, cleared and examined.

The study sites were visited on January 25, 1989 to record habitat conditions. Presence of snow, ice, air gap, water and sediment deposits above each basket was noted; depth of each was measured if present. Water velocity was estimated using the floating stick technique at the site or at a nearby openwater location. Water temperature was measured at the surface using a hand-held mercury thermometer, and in the substrate using a Fluke model 51 electronic thermometer with a 24 inch K-type thermocouple encased in stainless steel.

To ensure that all eggs had sufficient time to develop and hatch before removal on March 14, 1989, Daily Temperature Units (DTU) were calculated and compared to requirements described by Piper et al. (1982). One DTU is equal to one degree Farenheit above freezing (32°F) for a 24 hour period. Groundwater temperatures measured at each site in January were used in these calculations. Details are presented in Appendix 2. Calculations determined that all eggs should have had ample time to hatch by March 14.

Egg baskets were removed from all sites on March 14, 1989. Eggs or fry from each basket were examined immediately and classified as: dead eggs - with or without some development before death; dead fry - having hatched but died before removal; or, live fry. Dead eggs from 9-Mile and Wilson creeks were further categorized according to appearance and apparent stage of development before death. Fry and eggs were preserved in 5% formalin and shipped to Winnipeg. Fry which had been found live were measured in the lab using a disecting microscope with a graduated occular for total length, yolk sac length, yolk sac depth and yolk sac width.

During basket removal at CN Creek a sample of the sediment which had accumulated over the egg baskets was collected in a plastic bag. This sample along with the substrate removed from CN1, CN2 and CN3 baskets was sent to the Geotechnical Services

Section of the Engineering and Construction Branch, Manitoba Department of Natural Resources. Each sample was analysed for percent composition (dry weight) of various particle sizes using a series of U.S. standard sieves. Results were grouped into gravel (> 4.75 mm)and two classes of fines (<0.074 mm and <2.36 mm).

DATA ANALYSIS

No statistical analyses were performed on data from Wilson and 9-Mile creeks as all eggs from these streams were dead. Comparison of degree of development before death is not possible as some eggs were opaque and embryos could not be seen.

Data from egg baskets in CN Creek were analysed using the chi-square statistic (P = 0.05) (Huntsberger and Billingsley 1977) to determine whether egg development was equal among baskets. Dead eggs, dead fry and live fry were used as classes of development in each of the three baskets. For statistical purposes, the number of eggs which were unaccounted for (of the original 200) in CN1 (n=8) and CN2 (n=19) were assumed to have been dead eggs which disintegrated and were therefore added to the total of dead eggs present.

In CN3 both the number of dead eggs and the number of live fry were estimated. Most of the live fry had escaped when a seam was accidentally opened during basket removal. Therefore the number of eggs unaccounted for in CN3 (n=91) consisted of escaped fry and probably some disintegrated eggs. The number of disintegrated eggs is assumed to have been the same as that for CN2 (n=19) which was incubated under similar conditions. The remaining eggs unaccounted for (n=72) are assumed to have been escaped fry (since a large number were observed escaping). The total number of live fry is therefore estimated as 72 escaped plus 19 present for a total of 91.

CN3 also contained a large amount of debris from broken eggs.

The number of dead eggs which this debris represented (90) was estimated by separating it into groups visually equivalent to that produced when one egg was crushed. The total number of dead eggs is estimated as 90 crushed plus 19 missing for a total of 109.

As the chi-square analysis showed that development was not equal among baskets, and the differences in development appear greatest between CN3 and the other two baskets, a second chi-square test (P = 0.05) was performed to determine whether development was equal between the similar baskets, CN1 and CN2. Dead eggs, dead fry and live fry were again used as classes of development. As in the initial test, missing eggs were assumed to be disintegrated dead eggs. Results showed that development was equal in CN1 and CN2 so data were combined and a chi-square test (P = 0.05) of equal development in CN3 was performed.

Statistical analyses were also used to compare size of the live fry in baskets CN1, CN2 and CN3. Analyses were performed on a randomly selected sample of 18 fry from each basket. Comparisons were made of total fry length, yolk sac length, yolk sac depth and yolk sac width. Before comparisons were performed a chi-square test for goodness of fit (P = 0.01) (Huntsberger and Billingsley 1977) was performed on each data set to test the assumption that the data fit a normal distribution. All sets of data were determined to closely fit the normal distribution.

An analysis of variance (Huntsberger and Billingsley 1977) was performed for each measurement (total length; yolk sac length, depth and width) on the samples from CN1, CN2 and CN3. The results of each analysis of variance were used in an F-test (P = 0.01)

(Huntsberger and Billingsley 1977) to determine whether there were any differences in measurements among baskets. Since the results of the F-test for each of the four measurements showed that there were differences among baskets further comparisons were performed to determine between which baskets fry were significantly different. The value of Least Significant Difference (LSD) (Snedecor and Cochran 1967) was calculated (P = 0.05) for each measurement and used to compare means of the three baskets.

RESULTS

Physical Characteristics

Surface water temperatures when the egg baskets were buried in late September were 6.0°C in both CN and 9-Mile creeks, and 7.5°C in Wilson Creek. Physical characteristics measured in January, 1989 at each site are presented by stream in Table 1. Characteristics were equivalent at all three baskets in 9-Mile Creek. There was no openwater and velocity was very slow. Water temperature within the stream bed was notably lower at the egg baskets than along the bank, indicating greater groundwater influence nearer the bank.

The study site on CN Creek was ice free and flow was much faster than at 9-Mile Creek. A deposit of fine sediment had accumulated in varying depth over the baskets since they had been buried. Water temperature in the stream bed was more than twice as high as at 9-Mile Creek and substrate was very loose and soft. These characteristics indicate that the baskets in CN Creek were placed over a major groundwater upwelling.

The Wilson Creek study area was ice covered and flow was comparable to CN Creek. Water temperature in the stream bed was greater near the bank than at the baskets; neither temperature was as warm as CN Creek. Stream bed temperatures indicate that baskets in Wilson and 9-Mile creeks were not placed where greatest upwelling of groundwater occurred.

Table 1. Habitat conditions at egg basket sites on January 25, 1989.

	Baskets						
	9M1,2&3	CN1	CN2	CN3	W1	W2	W3
Depth (mm)							
Snow	27	0	0	0	0[a]	0[a]	0[a]
Ice	12	0	0	0	5.0	5.0	5.0
Air Gap	4	N/A	N/A	N/A	0	0	0
Water	26	10.0	6.5	5.5	16	12	9
Sediment	0	0	10.5	14.5	0	0	0
Water Temp. (C)							
at surface	0.5	--	--	--	--	--	--
in gravel at baskets	2.3	5.4	5.4	5.4	4.1	4.1	4.1
in gravel at bank	3.9	--	--	--	4.6	4.6	4.6
Water Velocity (m/s)	0.03	0.125	0.125	0.125	0.125	0.125	0.125

[a] Only the area immediately above baskets was free of snow.

Egg Fertility

The sample of brook trout eggs examined on October 13, 1988 was 84% fertilized; the sample examined on October 19, 1988 was 88% fertilized. Average percent fertilization of egg samples used in this study is therefore assumed to have been 86%.

Survival and Development

None of the eggs placed in 9-Mile and Wilson creeks survived to hatching. Some development had occurred in eggs from most of the baskets but does not appear to have progressed beyond the eyed stage. Detailed classification of eggs from each basket according to appearance may be found in Appendix 3.

Baskets removed from CN Creek contained live fry as well as dead eggs and some dead fry (Table 2). Some fry escaped from CN3 when a seam was accidentally opened during basket removal. It is most likely, and is assumed for statistical purposes, that the eggs missing from CN1 and CN2 were dead eggs which disintegrated. Therefore, the total numbers of eggs which died in CN1 and CN2 are 39 (19.5%) and 54 (27%) respectively. If 14% of the eggs in these two baskets had not been fertilized (assumed 86% fertilization in egg pool) then only 5.5% of viable eggs in CN1 and 13% of viable eggs in CN2 failed to develop. The number of dead eggs in CN3, as estimated from egg debris and assumed number disintegrated, is 109 or 40.5% of fertilized eggs.

The chi-square test of whether egg development (classes of development: dead eggs, dead fry and live fry) was equal among baskets in CN Creek determined that there were significant

Table 2. Numbers of eggs at various developmental stages in CN Creek baskets.

Basket	Dead Eggs	Dead Fry	Live Fry	Missing	Total
CN1	31	12	149	8	200
CN2	35	5	141	19	200
CN3	90[a]	0	19[b]	91[c]	200

[a] Estimated from egg debris.

[b] An unknown number escaped during basket removal.

[c] Includes both unaccounted for eggs (estimated as 19) and escaped fry (n=91-19=72).

differences (P = 0.05) (Appendix 4). Examination of the numbers of dead eggs, live fry and dead fry in each basket reveals that CN1 and CN2 are comparable while CN3 had notably poorer development. A chi-square test determined that development was equal (P = 0.05) in CN1 and CN2 (Appendix 4). A further chi-square test showed that development in CN3 was significantly different (P = 0.05) from that in CN1 and CN2 (combined data) (Appendix 4).

Fry Comparisons

Individual measurements of total length and yolk sac length, depth and width are presented for CN1, CN2 and CN3 in Appendix 5. Means and standard deviations of each measurement are presented by basket in Table 3. Mean fry length decreases from CN1 to CN2 and CN3, while yolk sac length, depth and width increase.

Analysis of variance tables (treatments: CN1, CN2 and CN3) for a subsample of data for each measurement may be found in Appendix 6. Subsequent F-tests (Appendix 6) showed that significant differences (P = 0.05; d.f. = 2,51) do occur among means of baskets.

The Least Significant Difference statistic (P = 0.05) was used to locate the differences among baskets. Mean length of fry was significantly greater in CN1 than in CN2 or CN3, and significantly greater in CN2 than in CN3. Means of yolk sac length and depth in CN1 were significantly smaller than in CN2 and CN3, while those of CN2 and CN3 were equal. Mean yolk sac widths of fry in CN1 and CN2 were equal, while they were significantly less in CN1 and CN2 than in CN3. Longer fry had smaller yolk sacs.

Table 3. Morphological characteristics of fry in baskets from CN Creek. All Measurements in mm.

Fry Measurement	CN1 (n=99)		CN2 (n=91)		CN3 (n=19)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Length	21.90	0.79	21.37	0.86	20.58	1.03
Yolk Length	5.08	0.29	5.32	0.33	5.40	0.50
Yolk Depth	1.57	0.37	1.88	0.29	2.00	0.37
Yolk Width	2.75	0.13	2.76	0.18	2.91	0.15

Substrate Composition

Observations of spawning areas in tributaries to the Nelson River reveal a large proportion of fine particles such as sand and silt in the substrate. The percentage of fine particles varies among spawning areas and streams, but is generally greater than 20% and may be as high as 60% (visual estimation).

Detailed seive analysis of substrate samples from within egg baskets at CN Creek, and from the sediment deposit which collected over the baskets, are presented in Appendix 7. Data are grouped as fine (2 classes) or coarse particles and presented in Table 4. Size divisions of 2.36 and 4.75 mm were chosen to characterize fine and coarse particles because they are comparable to those used by other reasearchers. Most researchers classify fine sediments as particles with diameters less than 6 mm (Chapman 1988), although some use 2 mm as the upper boundary (Hausle and Coble 19976; Sowden and Power 1985).

Table 4. Percentages of coarse and fine particles in substrate samples from CN Creek.

Sample	Fine Particles		Coarse Particles
	<2.36 mm	<4.75 mm	>4.75 mm
CN1	11.06	16.10	83.90
CN2	8.88	15.01	84.99
CN3	17.29	21.27	78.73
B1 (Sediment Deposit)	87.73	96.13	3.87

DISCUSSION

This attempt at experimental egg incubation has shown that habitat requirements for development and hatching of brook trout embryos in Nelson River tributaries are specific and not easily achieved. Locations chosen as suitable incubation sites in known spawning areas of 9-Mile and Wilson creeks were inadequate. The site chosen in CN Creek was suitable, however degree of development varied among baskets of eggs even though they were situated within 0.5 m of each other.

The factors which most likely influence incubation success in these tributaries include upwelling groundwater and stream substrate composition. The detrimental effects of fine substrate particles in salmonid redds has been documented by numerous researchers for over 60 years (Chapman 1988). Fine particles such as silt decrease permeability of substrate and inhibit flow of water past eggs (Hausle and Coble 1976; Sowden and Power 1985; Chapman 1988). Adequate flow is required to supply developing embryos and fry with oxygen and remove metabolic wastes (Coble 1961). Fine particles may also serve as a physical barrier to prevent or slow emergence of fry from within redds (Phillips et al. 1975; Hausle and Coble 1976). It has also been noted that where groundwater upwelling occurs at spawning areas fine substrate may not be as detrimental to development or emergence (Webster 1962; Sowden and Power 1985).

The spawning substrate in tributaries to the Nelson River contains a notable portion of fine substrate, much more than 20% which has been found to reduce survival of brook trout embryos (Hausle and Coble 1976). Habitat characteristics such as presence or absence of ice cover and surface water velocity generally affect embryo development by influencing the amount of oxygen in water and the degree of flow into and through the substrate. However, in tributaries to the Nelson River they may have little effect on embryo survival because the substrate is very fine and inhibits penetration of surface water. The trout which successfully reproduce in this habitat appear to spawn exclusively at sites of groundwater upwelling. Groundwater may provide the neccessary flow of oxygenated water to allow development in fine substrate. Upwelling may also serve to loosen the fine substrate, as noted when walking in groundwater areas, allowing fry emergence.

Temperatures measured within the stream bed indicate that sites chosen for incubation of eggs in 9-Mile and Wilson creeks were near but not at areas of greatest groundwater upwelling. Upwelling was probably inadequate and developing embryos died due to lack of oxygen and buildup of metabolic wastes.

Baskets placed in CN Creek were located where the portion of fine substrate was also greater than 20% (even before washout of the road crossing), but where there appears to have been vigorous groundwater upwelling. Analysis of substrate in each basket indicated that a significant amount of infiltration of fine particles had occurred since placement. Despite the presence of fine substrate within and surrounding the baskets at CN Creek embryos survived to hatching in each basket. Flow provided by groundwater may have served to supply necessary oxygen and remove wastes allowing development of embryos. However, survival to hatching, and size of fry did vary among baskets. Other researchers have found that survival to hatching and length of hatched fry decreased with decreasing oxygen availability to eggs (Silver et al. 1963; Shumway et al. 1964). It is possible that upwelling intensity varied among baskets simply because of location of each relative to the centre of the upwelling. It is also possible that the deposit of extremely fine substrate which drifted over egg baskets to variable depth served to partially "cap" and thereby decrease upwelling and oxygen delivery. Influence from the sediment deposit is suspected because the success of incubation within baskets was inversely proportional to the depth of sediment over baskets. It is important to note that this deposit was the result of sediment introduced when the stream crossing washed out in the previous two years.

Groundwater upwelling appears critical for development of brook trout embryos in the study area. If eggs are not placed where vigorous upwelling occurs embryos will probably not survive. Upwelling may decrease if fine sediments are deposited above eggs. During very cold winters streams may freeze completely or to the substrate even where groundwater upwelling generally prevents such freezing. Under these conditions upwelling may also decrease. Since degree of upwelling appears to be critical any decrease in flow may decrease embryo survival. It is essential therefore that construction activities do not add to the sediment load, or increase freezing, of spawning streams.

Further studies of egg development and measurement of habitat characteristics at incubation sites are necessary to determine whether these findings are common in all spawning areas. Other habitat variables may be influential in different streams in the study area.

CONCLUSIONS

1. Physical conditions necessary for successful incubation of brook trout eggs in Nelson River tributaries are specific and limited.

2. The primary factor influencing incubation appears to be groundwater upwelling at spawning areas. Embryo development may be successful only where groundwater upwelling occurs. Upwelling provides necessary flow around embryos and allows development even in fine substrate. Degree of upwelling appears to be critical.

3. Fine particles may block the flow of stream water through substrate, which generally delivers oxygen to and removes waste from embryos. Other factors such as surface water velocity or amount of ice cover appear to be inconsequential because of the overriding effect of fine substrate.

4. It is possible that groundwater upwelling may be decreased by capping of sites through sediment deposition or freezing of streams down to the substrate in cold winters. Any decrease in upwelling could significantly decrease incubation success of brook trout eggs.

RECOMMENDATIONS

1. In order to ensure continued reproductive success by brook trout during ongoing hydroelectric development construction activities must not add to the sediment load or increase freezing in spawning streams.

2. Further studies should be undertaken to better understand the habitat conditions necessary for successful brook trout egg incubation in the Nelson River system. In streams other than those studied here other habitat variables may also be influential.

3. Fertilized eggs should be similarly placed in nursery streams in an attempt to determine whether incubation is possible where spawning does not currently occur.

PART IV

BROOK TROUT TRANSFER TO KETTLE RIVER

PART IV

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INTRODUCTION

Construction of the Long Spruce Generating Station segmented the Kettle River within the Long Spruce Forebay and as such represents the first hydroelectric generating station in the lower Nelson River to directly impact a brook trout stream through reservoir creation. However, due to numerous additional impacts to the Kettle River (e.g. increased silt load and flow from the Butnau Diversion; sewage inflow from the town of Gillam) assessment of the effects of reservoir creation alone on brook trout stocks was not possible (Swanson 1986). Only four adult brook trout were found in the Kettle River during fisheries investigations in 1985 (Swanson 1986).

Aquatic habitat in the Kettle River-Long Spruce Reservoir system has since stabilized somewhat, especially as the banks of the Butnau Diversion stabilize. It is not known whether the current system is suitable for brook trout survival and reproduction. In an attempt to determine the response of brook trout to the current system 20 adults were transferred from the Limestone and Weir rivers, radio tagged and released into the Kettle River-Long Spruce Reservoir system in the fall of 1987 (Swanson et al. 1988). Several of these trout moved downstream and out of the reservoir shortly after release, perhaps due to disorientation magnified by the trout having been in spawning condition when transferred. For this reason it was suggested that transferring brook trout in the spring/summer, when they are less likely to be confused by spawning condition, might result in higher residency rates.

In 1988, a spring/summer transfer of brook trout was undertaken from French Creek and the Gods River to assess the responses of spring transferred brook trout to the Kettle River-Long Spruce Reservoir system. The transfer was also intended to develop a suitable method for transferring adult trout and to aid in assessing the feasibility of supplementing the depleted Kettle River trout population via adult trout transfers.

METHODS

Trout Transfer

A total of 31 adult brook trout were captured: 28 from the Gods River and 3 from French Creek. Twenty-five of these trout were successfully transferred to the Kettle River or its tributary 9-Mile Hole Creek (Figure 1): 22 of the 28 Gods River trout on June 27, 1988 and all 3 of the French Creek trout on June 28, 1988. Six of the Gods River trout died in transit.

The brook trout were captured by angling and were held in hoop nets for up to three days in their stream of origin before transfer. Trout were transferred without anaesthetic to Gillam on a Government Air Turbo Beaver. Two 100 l metal tubs aerated with compressed oxygen were used to hold the trout. Trout were then transferred into 200 l un-aerated garbage pails and transported by Bell 206 helicopter from Gillam to holding-pen sites on the Kettle River and 9-Mile Hole Creek. The duration of the transfer was approximately one and one half hours.

Radio Telemetry

Nine brook trout (seven from Gods River and two from French Creek) were tagged with 15 g, externally mounted 200-day life radio tags. Tagging procedures were as described in Swanson (1986) and brook trout were released at the two holding-pen sites in the Kettle River on June 29, 1988. Lengths and weights of radio-tagged brook trout are presented in Table 1. The remaining trout were tagged with Floy spaghetti tags and released.

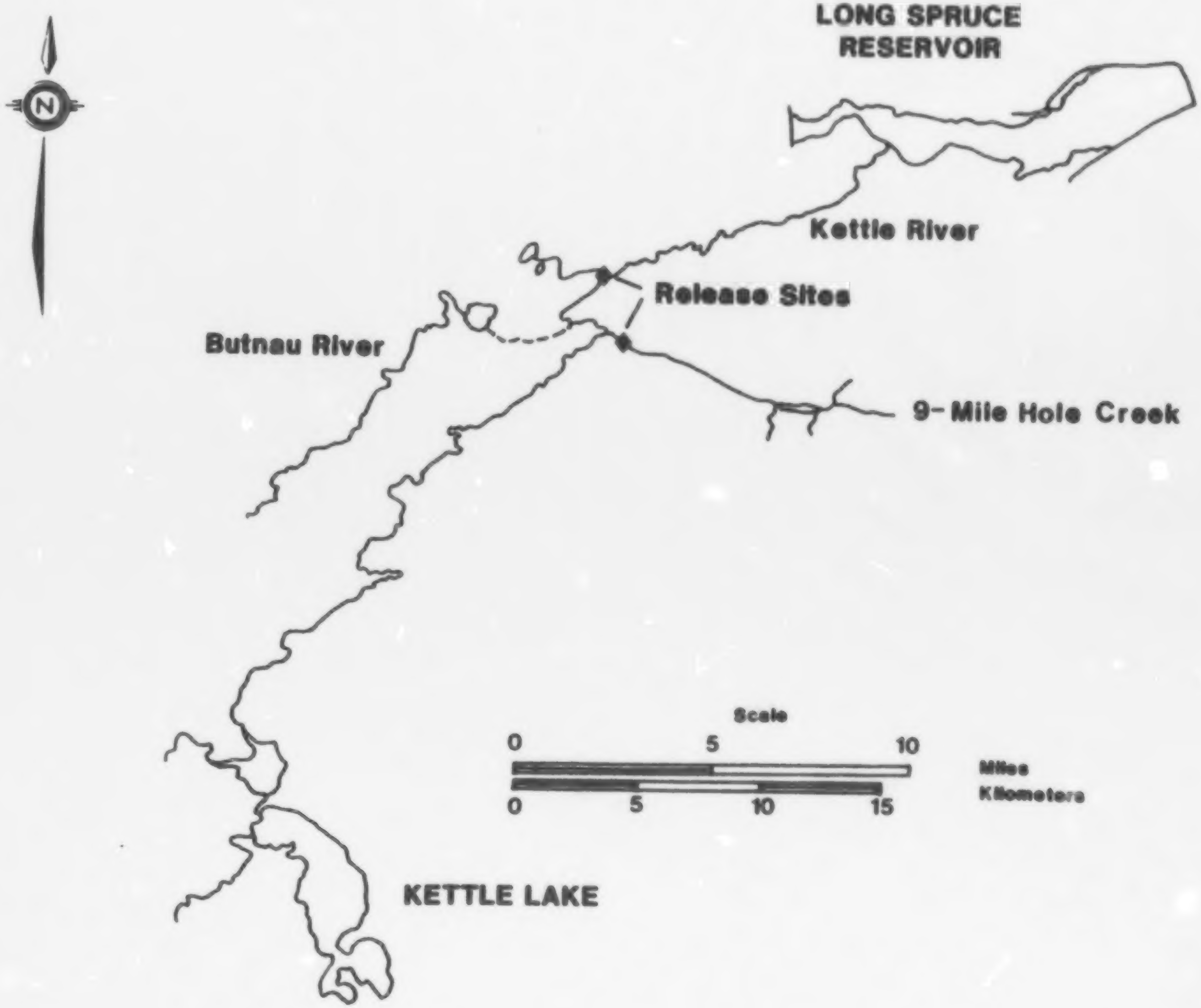

LONG SPRUCE
RESERVOIR
Kettle River
Release Sites
Butnau River
9-Mile Hole Creek
N
Scale
0
5
10
Miles
0
5
10
15
Kilometers
KETTLE LAKE

Fig. 1. Release locations for brook trout transferred into the Kettle River in 1988.

Table 1. Sizes of radio-tagged trout transferred into the Kettle River in 1988.

Stream of Origin	FL (mm)	Weight (g)	Tag Frequency (Mhz)
Gods River	454	830	49.828
	480	1100	49.909
	452	850	49.408
	460	860	49.318
	458	850	49.358
	430	680	49.787
	430	680	49.289
French Creek	466	870	49.869
	415	620	49.388

Radio-tagged brook trout were located approximately bi-weekly using a one-quarter wavelength directional loop antenna mounted on a Bell 206 helicopter as in previous studies (Swanson 1986; Swanson and Kansas 1987; Swanson et al. 1988).

RESULTS

Trout Transfer

The 31 brook trout which were captured and moved from French Creek and Gods River were all in good condition upon arrival in Gillam. Subsequently, during transfer into the un-aerated garbage pails and the flight to the Kettle River system, 6 of the 28 Gods River trout died. The three trout from French Creek were all successfully transferred.

Radio Telemetry

Information from two of the nine radio-tagged brook trout is of little use. One of these radio tags (49.787 Mhz) was not located after the trout to which it was attached was released on June 29, 1988. The other tag, 49.289 Mhz (Figure 2), was located for a brief period in the Long Spruce Reservoir until returned by a local angler claiming to have found the tag on the upstream side of the Long Spruce Generating Station forebay dike. Locations recorded for the remaining seven tags are presented in Figures 3 - 9. These seven brook trout remained in the Kettle River throughout the summer and fall of 1988.

Two of the seven trout were those transferred from French Creek. One (49.869 Mhz) was located near a historical trout spawning area during the spawning season (Figure 3). The other remained in 9-Mile Hole Creek, where it was released, exhibiting only local movements throughout the experiment (Figure 4).

The other five trout which remained in the system were from

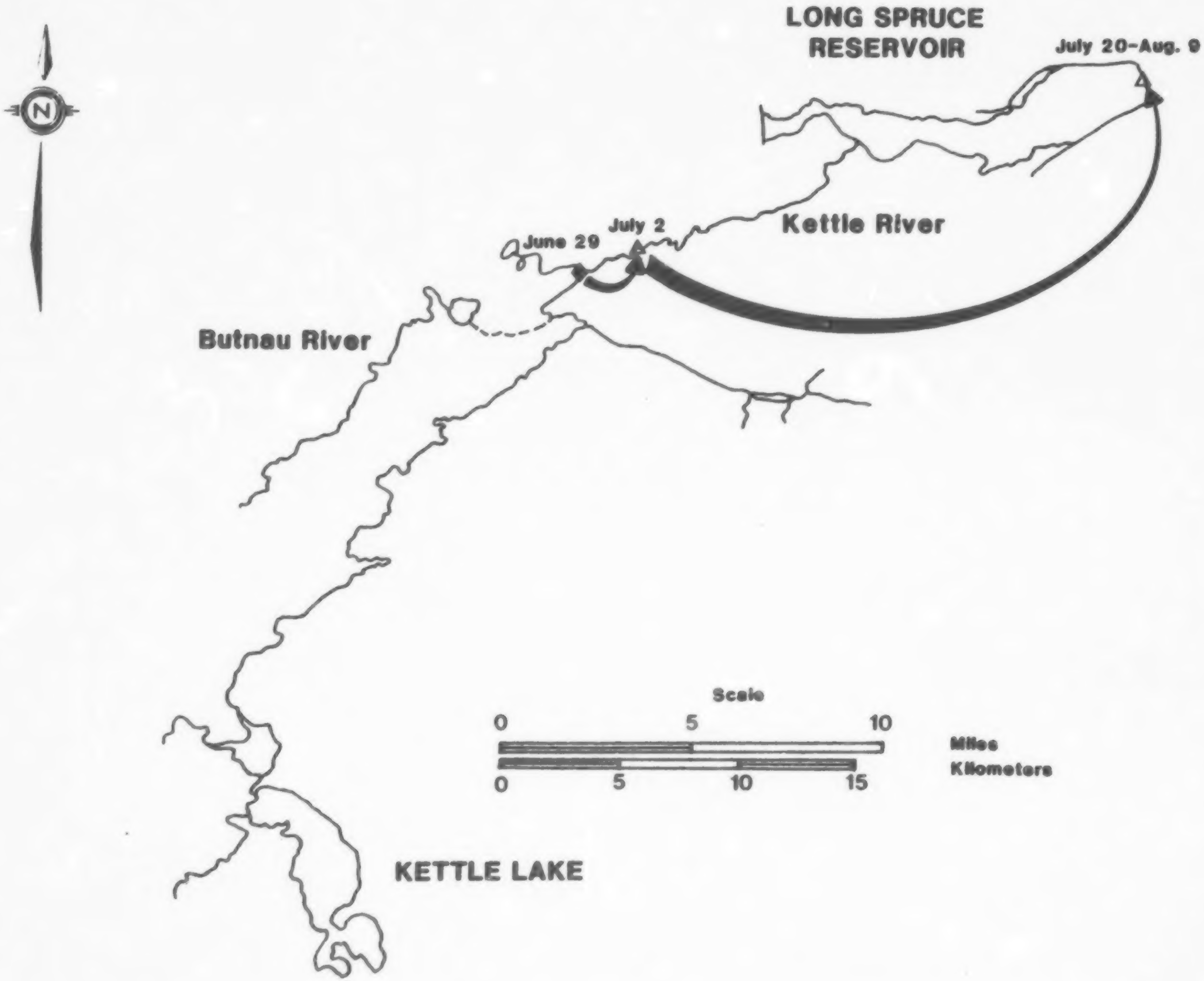

LONG SPRUCE RESERVOIR
July 20-Aug. 9
Kettle River
July 2
June 29
Butnau River
N
Scale
0
5
10
Miles
0
5
10
15
Kilometers
KETTLE LAKE

Fig. 2. Locations of radio-tagged brook trout 49.289 Mhz in 1988.

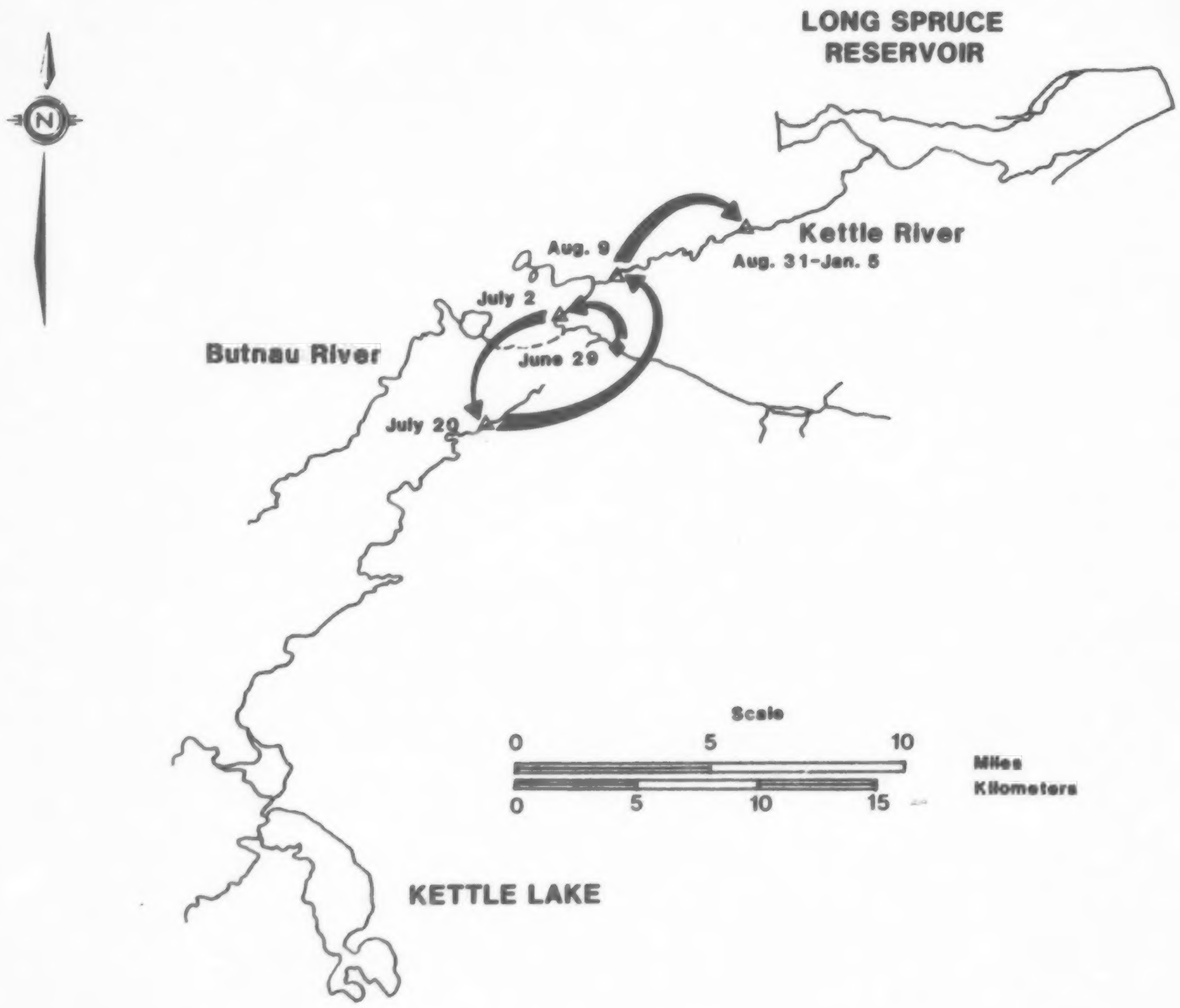

LONG SPRUCE RESERVOIR
Kettle River
Aug. 31-Jan. 5
Aug. 9
July 2
Butnau River
June 29
July 20
Scale
0
5
10
Miles
0
5
10
15
Kilometers
KETTLE LAKE
N

Fig. 3. Locations of radio-tagged brook trout 49.869 Mhz in 1988.

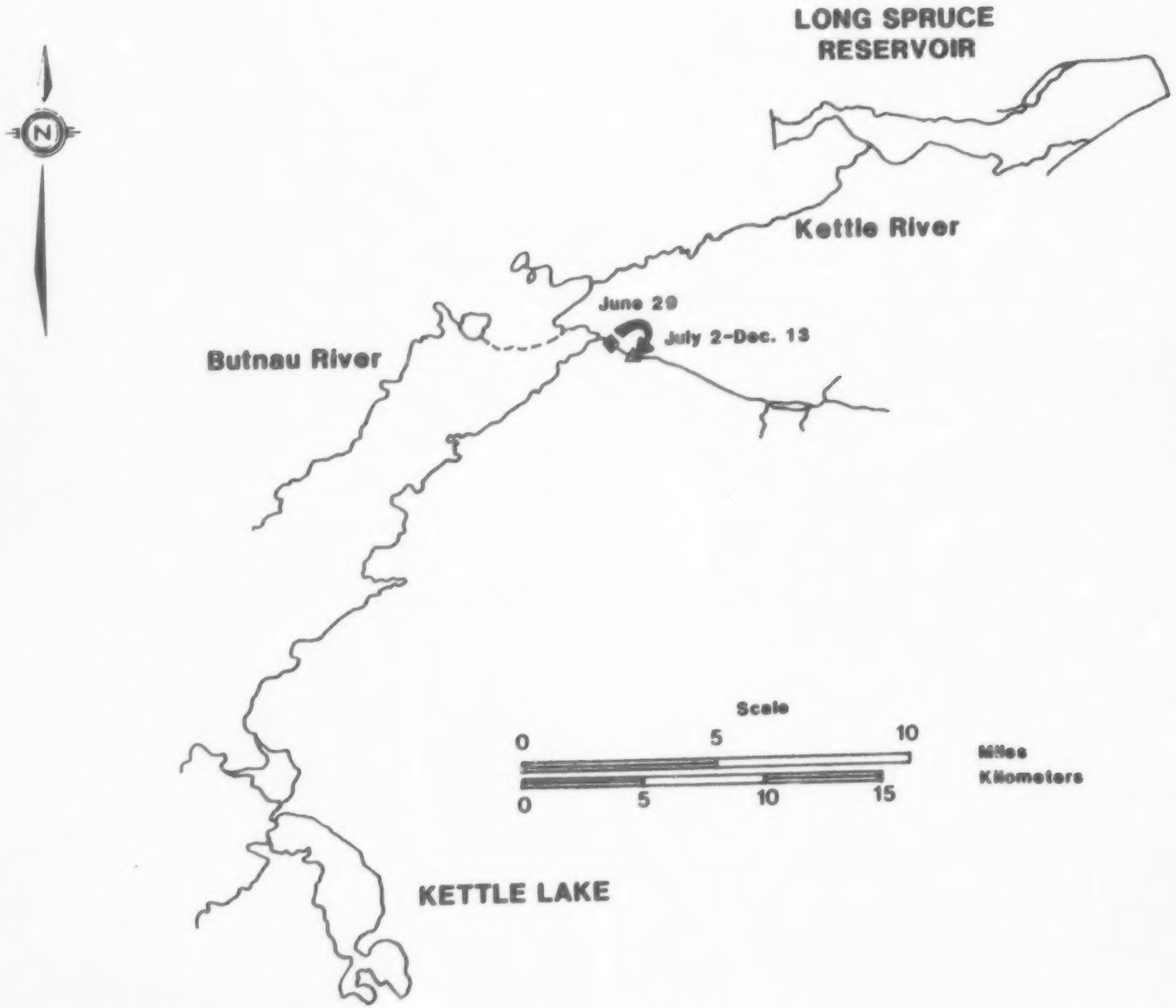

LONG SPRUCE RESERVOIR
Kettle River
June 29
July 2-Dec. 13
Butnau River
N
Scale
0
5
10
Miles
Kilometers
0
5
10
15
KETTLE LAKE

Fig. 4. Locations of radio-tagged brook trout 49.388 Mhz in 1988.

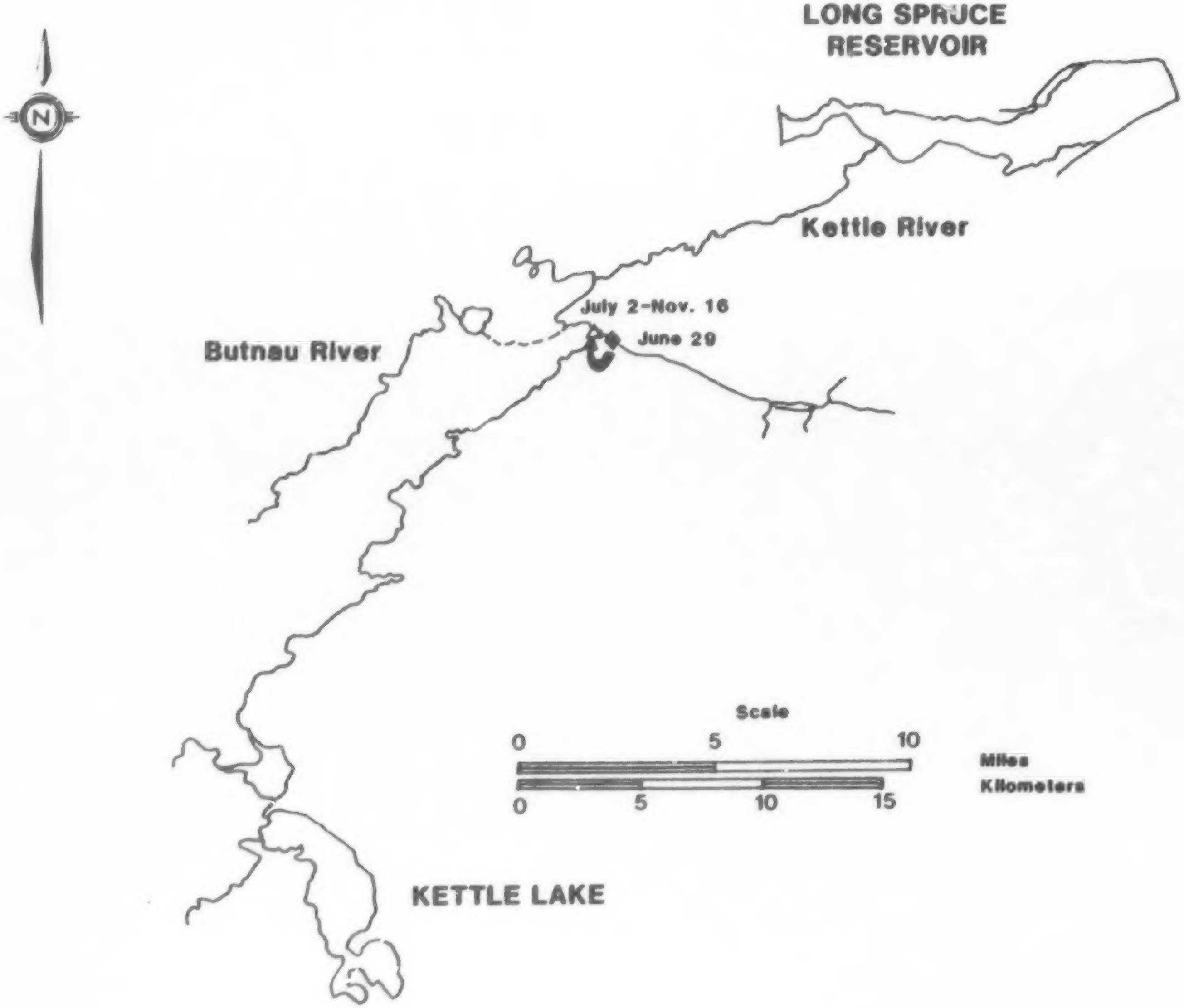

N
LONG SPRUCE
RESERVOIR
Kettle River
July 2-Nov. 16
June 29
Butnau River
Scale
0
5
10
Miles
0
5
10
15
Kilometers
KETTLE LAKE

Fig. 5. Locations of radio-tagged brook trout 49.408 Mhz in 1988.

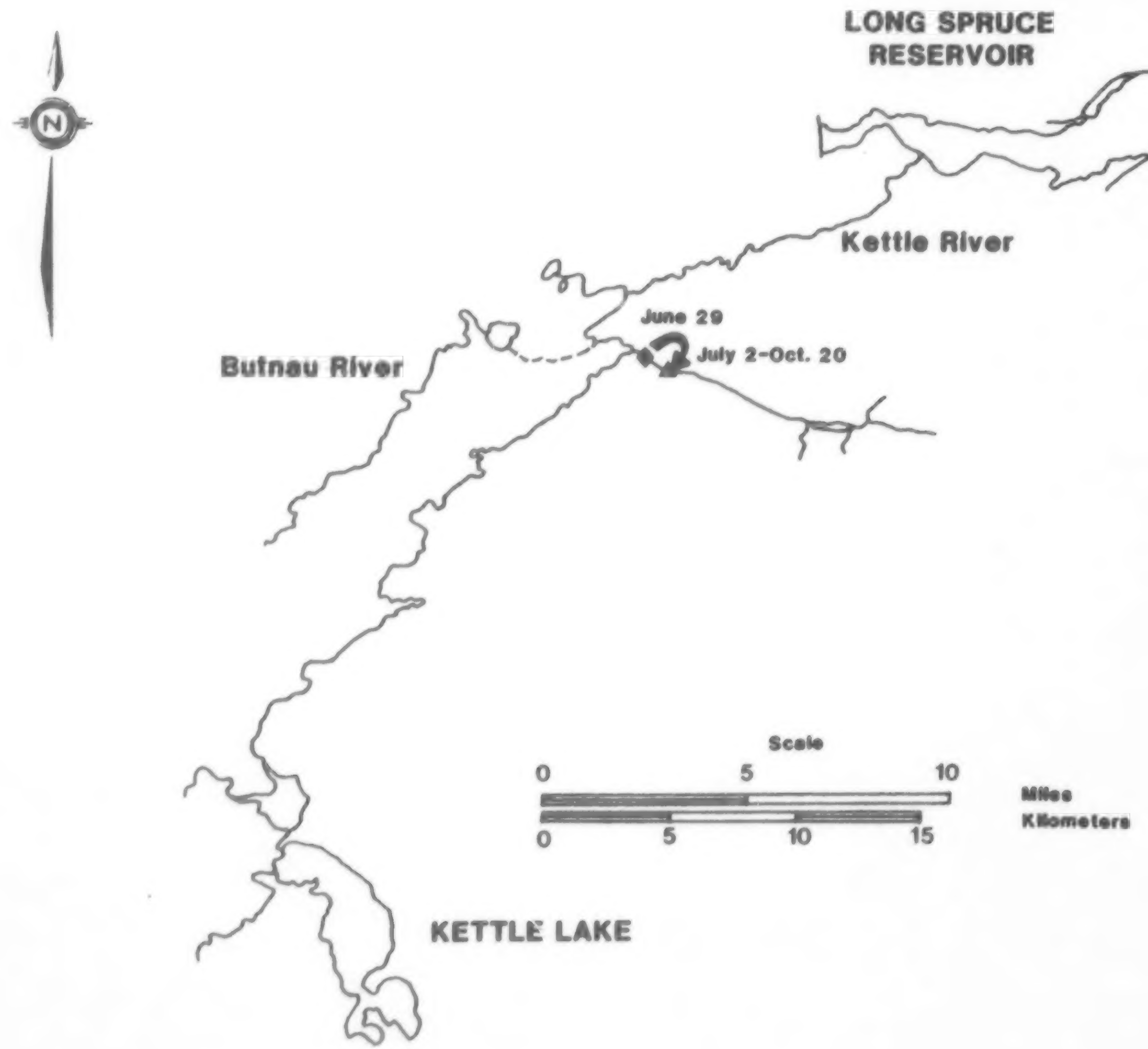
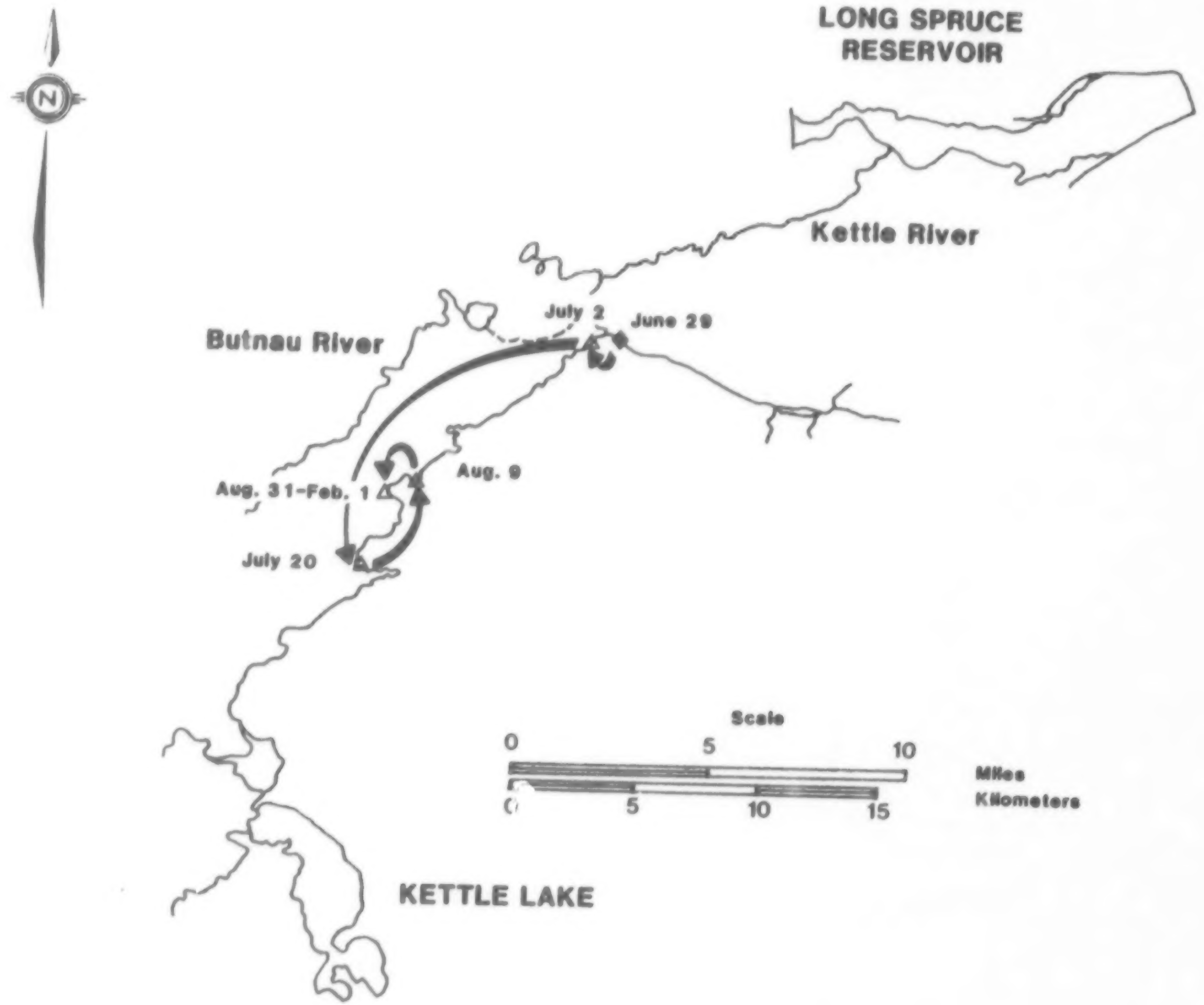

N
LONG SPRUCE RESERVOIR
Kettle River
June 29
July 2-Oct. 20
Butnau River
Scale
0
5
10
Miles
0
5
10
15
Kilometers
KETTLE LAKE

Fig. 6. Locations of radio-tagged brook trout 49.358 Mhz in 1988.



N
LONG SPRUCE RESERVOIR
Kettle River
Butnau River
July 2
June 29
Aug. 9
Aug. 31-Feb. 1
July 20
Scale
0
5
10
Miles
0
5
10
15
Kilometers
KETTLE LAKE

Fig. 7. Locations of radio-tagged brook trout 49.909 Mhz in 1988.

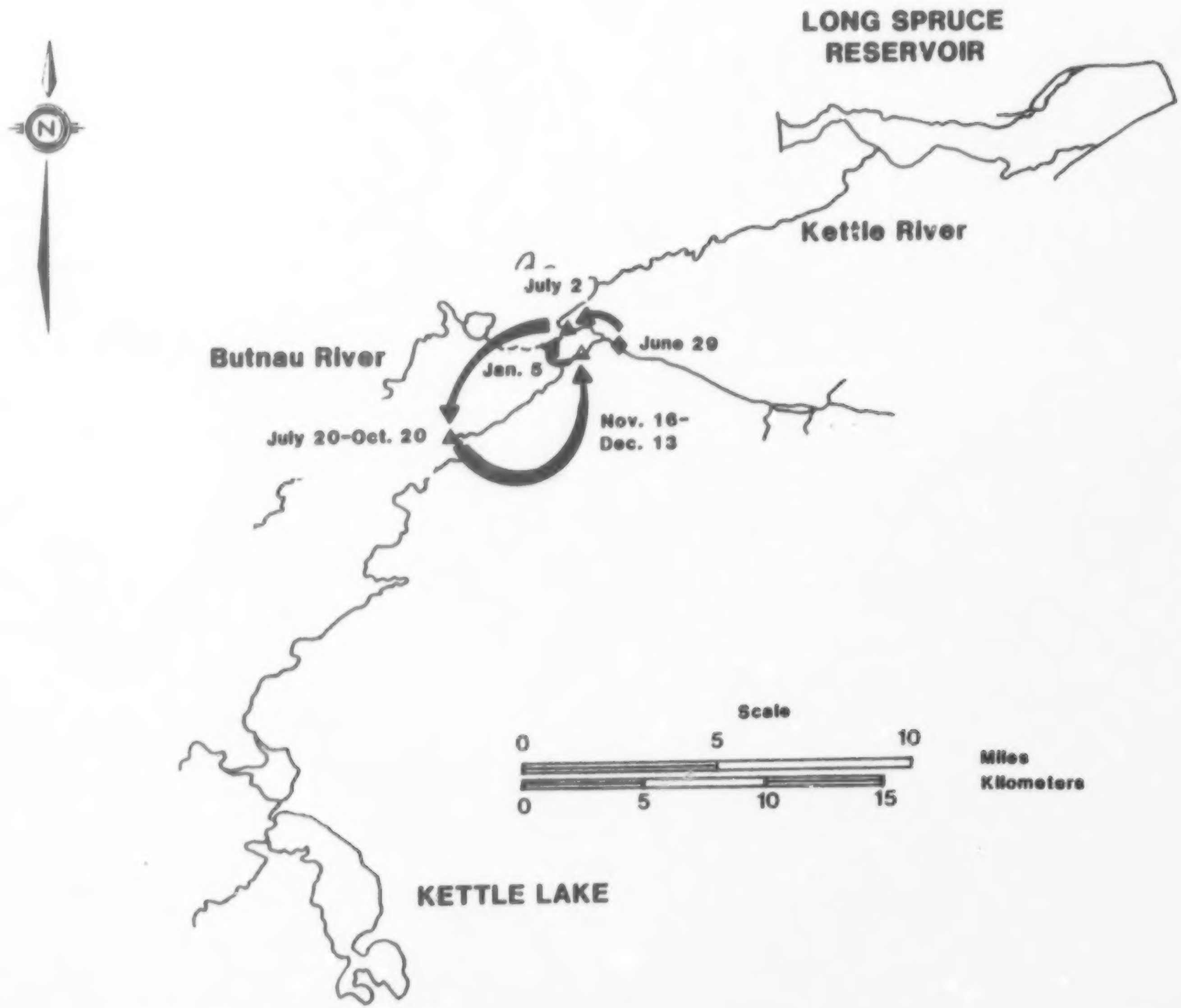

N
LONG SPRUCE
RESERVOIR
Kettle River
July 2
June 29
Butnau River
Jan. 5
Nov. 16-
Dec. 13
July 20-Oct. 20
Scale
0
5
10
Miles
Kilometers
0
5
10
15
KETTLE LAKE

Fig. 8. Locations of radio-tagged brook trout 49.318 Mhz in 1988.

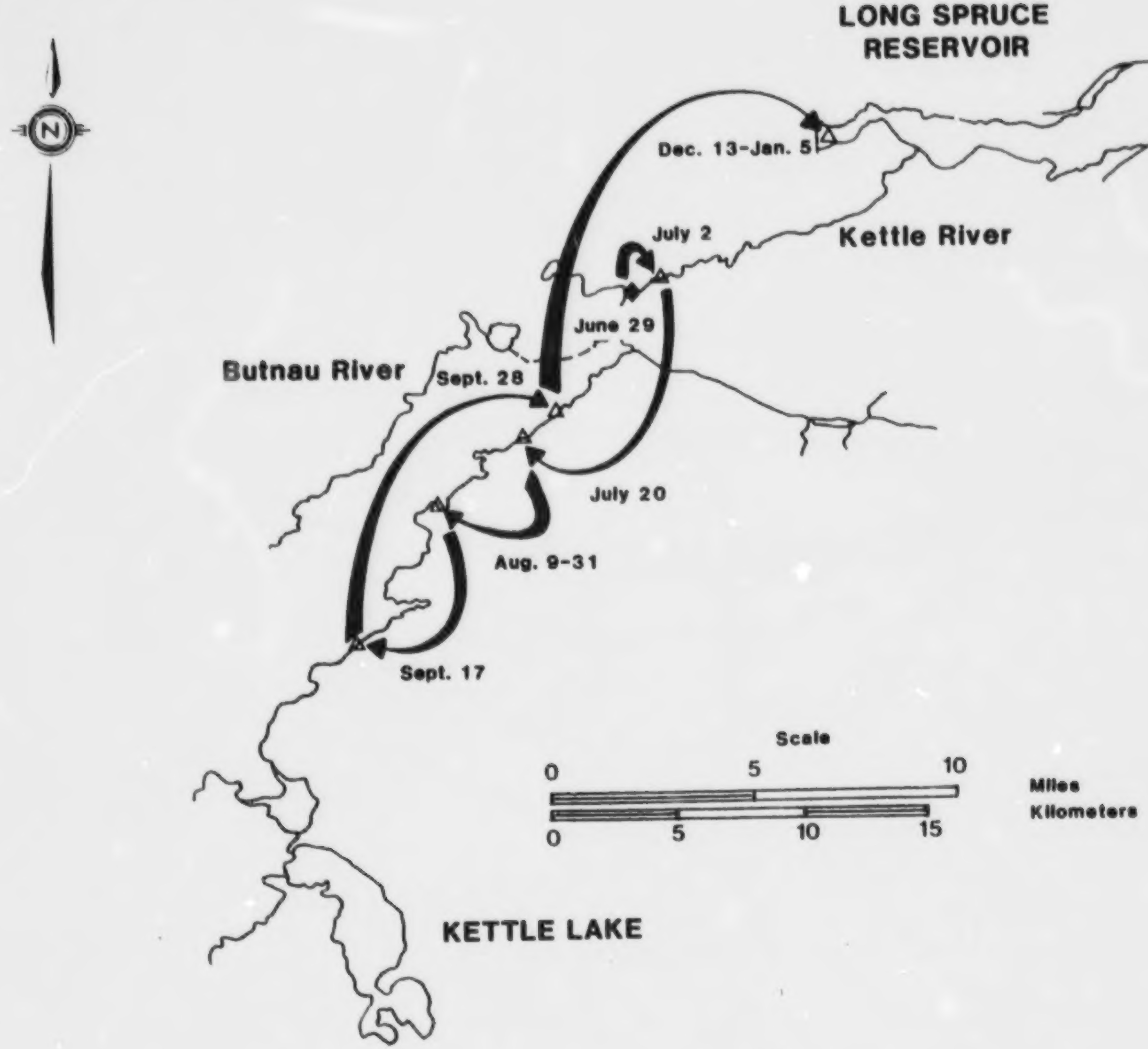

LONG SPRUCE
RESERVOIR
Dec. 13-Jan. 5
July 2
Kettle River
June 29
Butnau River
Sept. 28
July 20
Aug. 9-31
Sept. 17
Scale
0
5
10
Miles
Kilometers
0
5
10
15
KETTLE LAKE
N

Fig. 9. Locations of radio-tagged brook trout 49.828 Mhz in 1988.

the Gods River. Two remained in 9-Mile Hole Creek from summer through winter of 1988/89 (Figures 5 - 6; 49.408 and 49.358 Mhz), two moved quite extensively but remained in the Kettle River (Figures 7 - 8 ; 49.909 and 49.318 Mhz) and one moved extensively within the Kettle River during the openwater season then moved into the Kettle Generating Station tailrace in December (Figure 9; 49.828 Mhz). All of the trout located in the Kettle River were situated in or near rapids during the openwater season.

DISCUSSION

Trout Transfer

While the transfer of trout in the aerated tubs worked well the subsequent transfer of trout into 200 l garbage pails for movement by helicopter did not. The garbage pails were used because, while the aerated tubs were suitable for transfer in the Turbo Beaver, they were too cumbersome to be moved into the helicopter for transfer to the holding pen sites. The six mortalities occurred because of a combination of factors: 1) the pails were not aerated, 2) additional handling stress resulted from transfer of these trout to the pails, and 3) there was a minor delay in arrival of the helicopter. The use of a more portable system which could be moved from the fixed wing aircraft to a helicopter and which could aerate continuously would reduce stress on the fish. This would have enabled the successful transfer of 31 rather than 25 adult trout.

Radio Telemetry

The reason for disappearance of radio tag 49.787 Mhz is not known. It is possible that this fish moved out of the system, although it was not located downstream during an extensive tracking flight on July 2, 1988. It is possible that the tag malfunctioned and ceased transmission. Similarly, the demise of the trout bearing radio tag 49.289 Mhz is unexplained. The tag, which a local angler claimed to have found on the Long Spruce Generating Station forebay dike, may have fallen off of the trout, but it seems unlikely that it would wash up at the reported location. It is more probable that either a raptor caught the trout and left the carcass to rot away from the tag, or an angler caught the trout downstream of the dam and disposed of the tag upstream of the dike.

Movements of the seven radio-tagged brook trout which remained in the Kettle River system indicate that trout transferred in the spring/summer are less likely to leave the system than those transferred in fall when in spawning condition (Swanson et al. 1988). Tracking results indicated that the trout had found suitable summer feeding habitat within the rapids of the Kettle River. The fact that one trout was located near the Gillam spawning pool from August 31 onward (49.869 Mhz) indicates that this trout may have attempted to spawn in the Kettle River. These data support the conclusion that brook trout transferred into the Long Spruce Reservoir system in fall of 1987 did not leave the Kettle River in response to environmental factors, but did so due to disorientation which may have been magnified by spawning condition (Swanson et al. 1988).

Behaviour of radio-tagged trout 49.828 Mhz which was located in the Kettle Generating Station tailrace in the winter of 1988/89 was similar to that of radio-tagged brook trout transferred in the fall of 1987. Two of the trout which remained in the reservoir over the winter of 1987/88 were located frequently in the Kettle Generating Station tailrace. Perhaps the open water attracts trout to the generating station.

CONCLUSIONS

1. The brook trout transfer mortality was a consequence of increased handling stress and low oxygen levels associated with moving brook trout into unaerated containers and flying them to the holding pen sites by helicopter.

2. Brook trout appear to have been less affected when transferred to a strange river system in the spring/summer than in the fall, and remained resident in the Kettle River-Long Spruce Reservoir throughout the transmitting life of the radio tags.

RECOMMENDATIONS

1. A portable transfer unit should be developed which could hold sufficient numbers of adult trout and be moved intact from the fixed-wing aircraft to a Bell 206 helicopter.

2. Annual transfers of adult brook trout should be undertaken to supplement the depleted Kettle River stocks thereby encouraging development of a self-sustaining population.

PART V

BROOK TROUT MONITORING

PART V

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INTRODUCTION

In response to concerns raised in the Limestone Generating Station Environmental Impact Study (MacLaren Plansearch Inc./Intergroup Consultants Ltd. 1985) long-term monitoring of brook trout stocks within the Limestone Forebay and Limestone River was initiated. Monitoring studies included: 1) juvenile brook trout stream utilization, 2) larval brook trout drift, 3) adult spawning populations and 4) Floy tag recaptures. Floy tagging was initiated in 1985. Monitoring of stream use by juveniles began in 1986 as part of a trout habitat inventory. Larval drift and spawning population studies commenced in 1987. The objective of these studies was to monitor brook trout life stages and strategies throughout the construction of the Limestone Generating Station and for a significant number of years after impoundment to assess the impacts of hydroelectric development on brook trout stocks in the area. This report outlines the study sites, the methods and the data collected in 1988. Some discussion of the results is included where qualification of the data is required or comparison with previous years is useful.

METHODS

Stream Utilization

Fifteen sites on five Nelson River tributaries were electrofished in each of 1986, 1987, and 1988. Moondance, Beaver, Swift, Tiny and Goose creeks were sampled in the previously designated electrofishing sections described in Swanson and Kansas (1987) (Figure 1). Three sites on CN Creek were electrofished in 1987 and 1988, and three sites were electrofished in each of Brooks Creek and an unnamed creek "15 Creek" in 1988 (Figure 1). In 1988, sampling was conducted during two periods: July 15-25 and August 4-14. All sites were sampled in each period except Fifteen Creek Site 1, which was only sampled during the August 4-14 period.

Sites were sampled following Swanson and Kansas (1987) wherein the entire 100 m of each site was electrofished from top to a seine at the bottom. When the entire 100 m could not be sampled those subsections which had been electrofished were recorded for subsequent determination of area sampled. Three electrofishing passes were performed to attempt removal technique population estimates (Ricker 1975). If data did not permit calculation of removal estimates then total number caught and total weight were used in catch per unit effort determination. The lengths and weights of all trout were measured. Weight of young of the year trout was estimated by volume displacement. Trout longer than 17 cm were also sampled for aging structures (scale sample) and were Floy tagged and released. The frequencies of other species captured were recorded, however, only brook trout data are reported

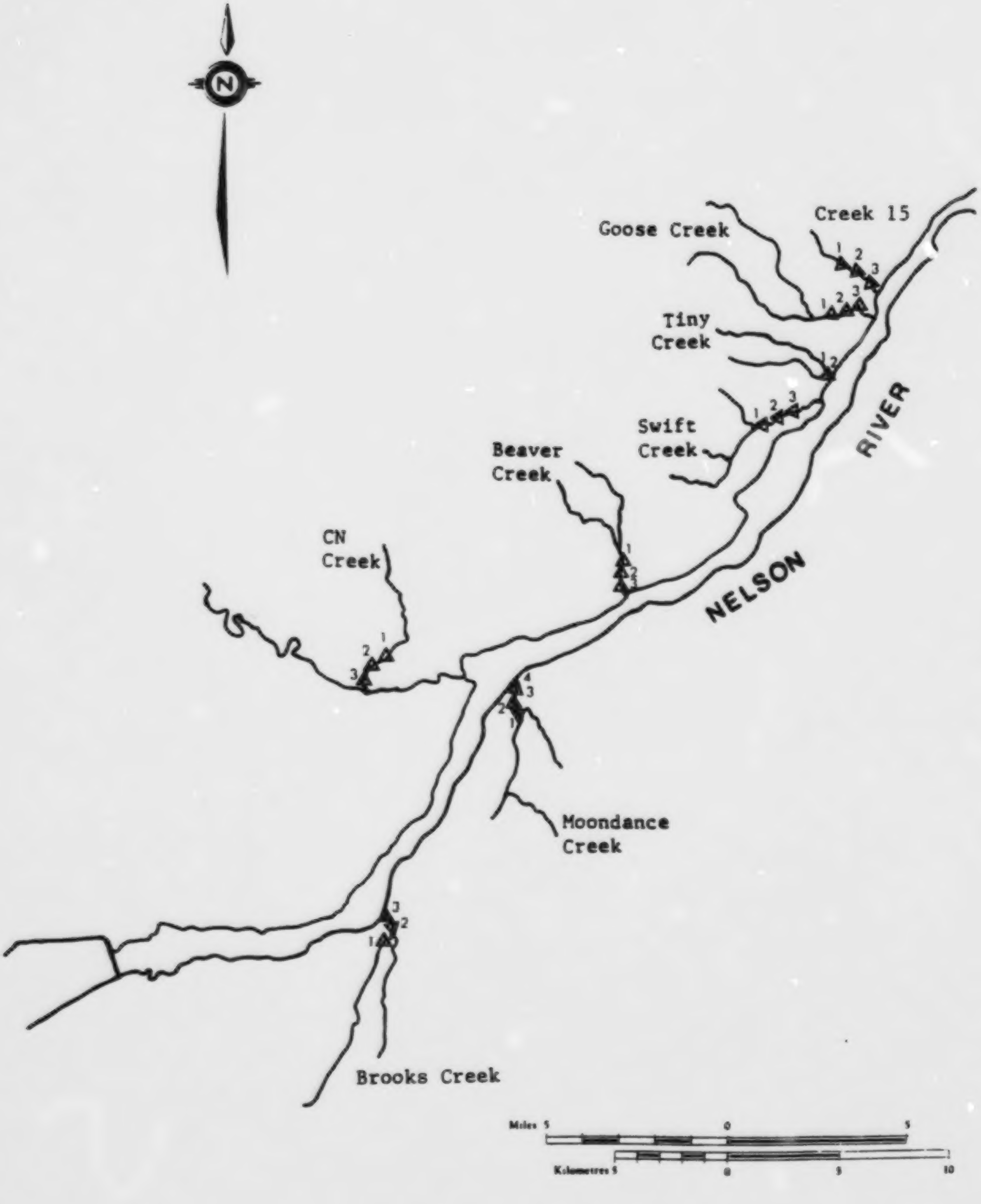

N
Creek 15
Goose Creek
Tiny Creek
Swift Creek
Beaver Creek
CN Creek
NELSON
RIVER
Moondance Creek
Brooks Creek
1
2
3
4
Miles 5
0
5
Kilometres 5
0
5
10

Fig. 1. Locations of electrofishing sites sampled in 1988.

here.

In 1987 and again in 1988 additional electrofishing was conducted in CN Creek for mark-recapture population estimation. The site used was a 400 m long reach located below electrofishing section 3 near the spawning area associated with groundwater upwellings. Numbers of trout present were estimated using modified Petersen and modified Schnabel estimates (Ricker 1975).

Additional electrofishing was also conducted in 1988 on an unnamed Nelson River tributary located immediately downstream of the Limestone River and just west of the town of Sundance. This electrofishing was done at Manitoba Hydro's request and related to maintenance work to be done on a damaged culvert crossing on this creek.

Larval Drift

Monitoring of larval brook trout drift in 1988 was conducted using equipment and techniques described in Swanson and Kansas (1987). Two drift traps were placed side-by-side in each of three Limestone Forebay tributaries which had harboured spawning brook trout in 1986 and 1987 (Sky Pilot, Leslie and Wilson creeks; Figure 2). Two drift traps were also used side-by-side in each of three Limestone River spawning tributaries (12-Mile, 9-Mile and CN creeks) as experimental controls to aid in assessing the Limestone Forebay drift results and also to gather preimpoundment data on Conawapa Forebay streams (Figure 2). In Leslie Creek two additional traps were placed separately at two locations upstream of the highway crossing well above the monitoring drift trap site

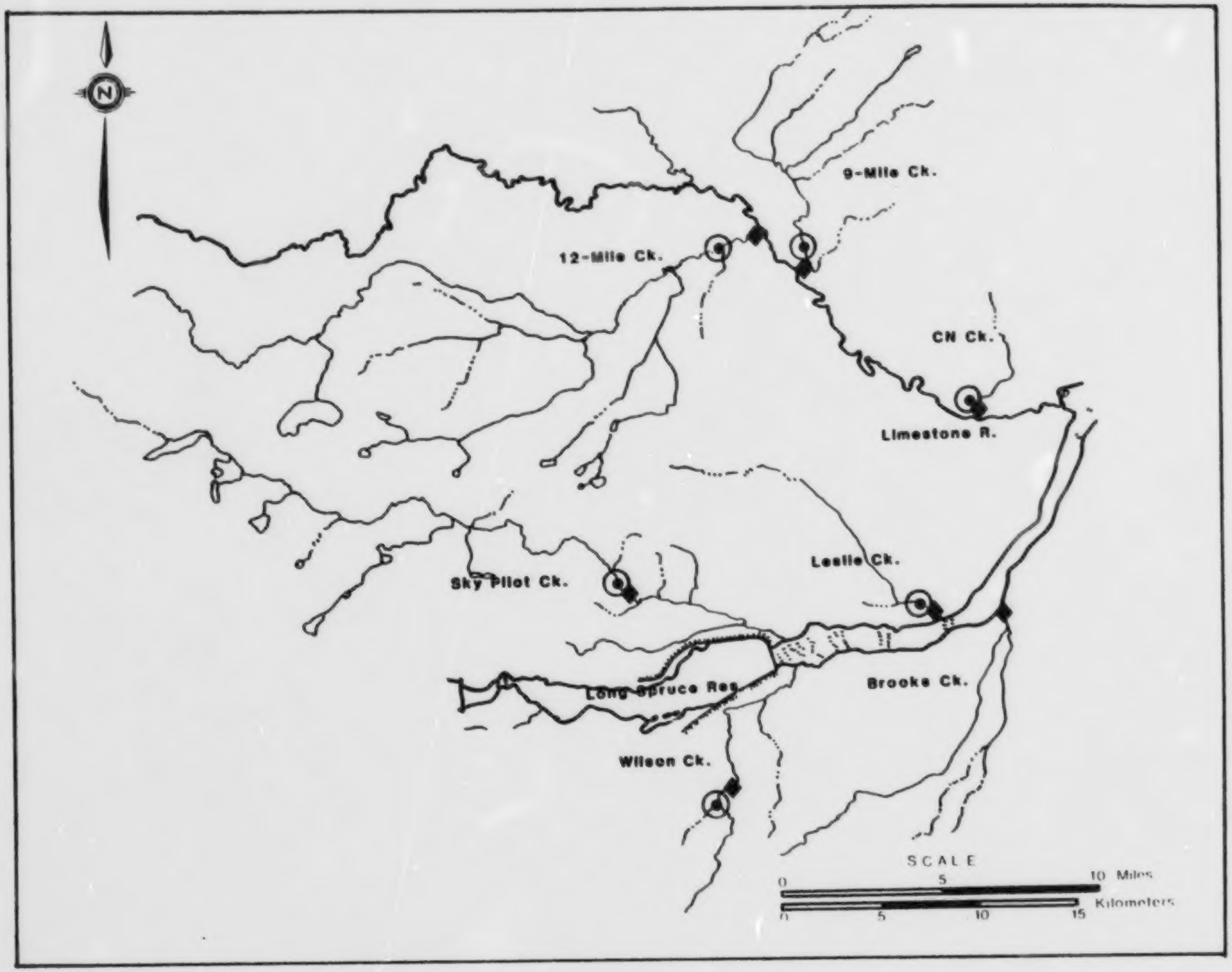

N
9-Mile Ck.
12-Mile Ck.
CN Ck.
Limestone R.
Leslie Ck.
Sky Pilot Ck.
Brooke Ck.
Long Spruce Res.
Wilson Ck.
SCALE
0
5
10 Miles
Kilometers
0
5
10
15

Fig. 2. Drift trap locations and brook trout spawning areas in the study area in 1988. Diamonds are drift trap locations.

to assist in locating the spawning area in that stream. In Brooks Creek two drift traps were placed near the mouth to determine whether brook trout spawn in this stream (Figure 2).

Traps were checked daily through the study period (May 9 - June 20). At each location all debris in each trap was collected, sorted and all brook trout captured were enumerated.

Stage-discharge relationships were established for each of the study streams at or near the drift trap locations in 1988. A 2 m long metal post was pounded into the stream bed and a 2 m staff gauge was bolted to it. Daily stage measurements were estimated to the nearest millimetre by eye. When receding water levels necessitated relocation of the gauge to deeper water, before and after readings were taken to maintain continuity of recordings. A minimum of three discharge measurements was taken in each of the seven streams studied in 1988. Water velocities were measured at (0.6 X depth) using a hand-held Price Current Meter. Due to extreme flows peak discharges could not be measured, but were estimated using the stage-discharge relationship.

Spawning Populations

Two-direction counting fences were used to sample adult brook trout in five streams in 1988 (Figure 3). Four of these streams (Sky Pilot, Wilson, 9-Mile and 12-Mile creeks) had also been sampled in 1987. Leslie Creek was sampled for the first time in 1988. No fence was constructed in Brooks Creek as no evidence of spawning was found during drift sampling or electrofishing.

Fences were operated between September 2 and October 20. This

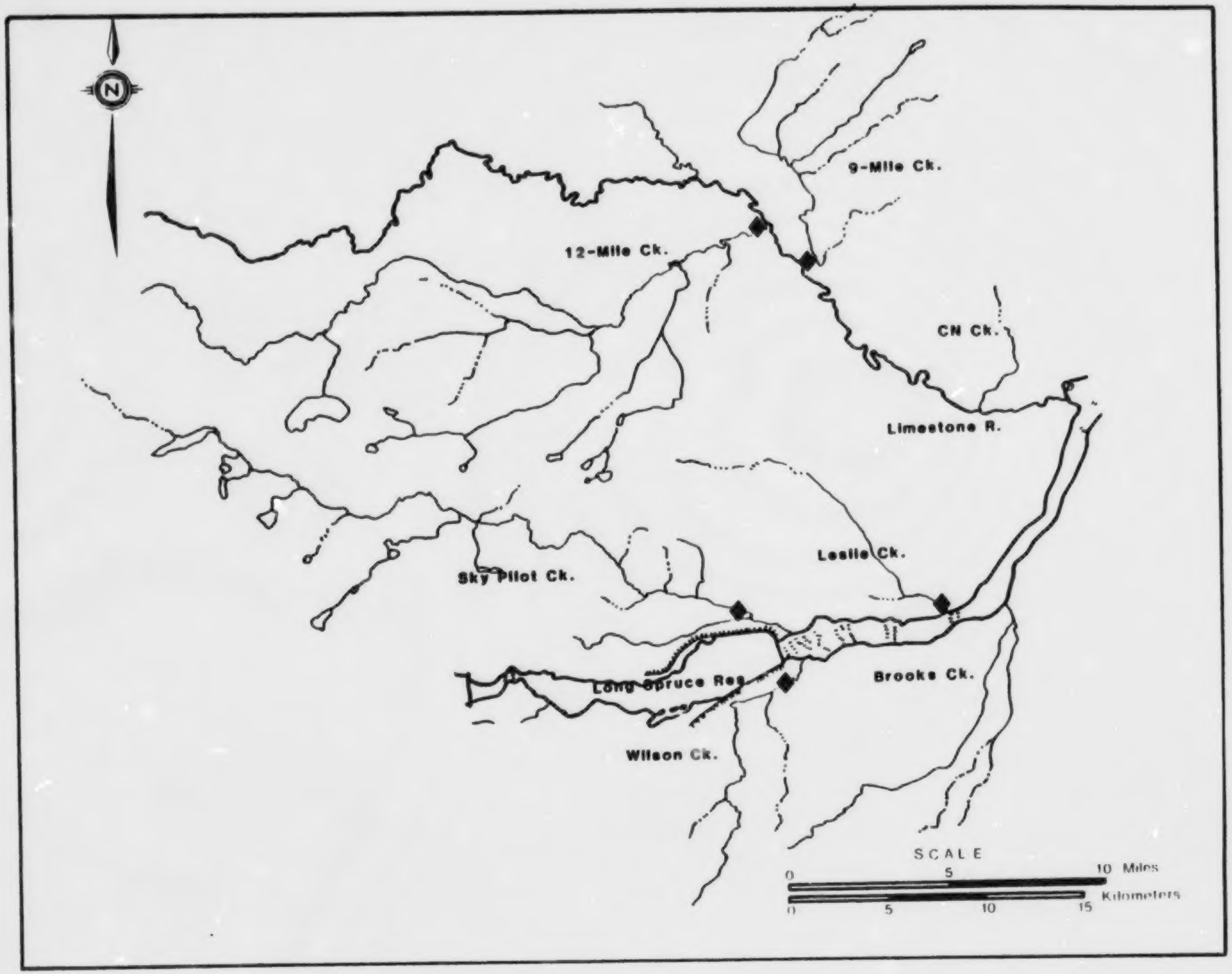

N
9-Mile Ck.
12-Mile Ck.
CN Ck.
Limestone R.
Leslie Ck.
Sky Pilot Ck.
Long Spruce Res.
Brooks Ck.
Wilson Ck.
SCALE
0
5
10 Miles
Kilometers
0
5
10
15

Fig. 3. Fish fence locations for the study streams in 1988.

period of operation was based on 1987 studies during which the majority of trout were captured moving downstream following spawning. A rapid drop in water temperature appears to have precipitated the migration.

Fences were checked twice daily on all creeks except 12-Mile which was checked once daily due to access restraints. Each captured trout was weighed (g) and measured (fork length, mm), scales were removed for ageing, a Floy tag was attached and the fish was released. The direction in which the fish was moving when captured was recorded, as was the sampling time and date. Water temperatures were recorded each time the fence was checked. Fence maintenance was also done each time a site was visited and included cleaning accumulated debris off the fence, reinforcing fence support structures and maintaining fence integrity (ensuring no holes developed under or around the fence).

Floy Tagging

Following Gaboury (1978, 1980) all brook trout greater than 17 cm fork length that were sampled and released in the field seasons of 1985-88 were tagged with individually numbered spaghetti tags. Tags were anchored between interneural spines at the posterior insertion of the dorsal fin. A pelvic fin was removed for strontium analysis, and also served as a double mark for assessing tag loss. Upon recapture, location was recorded and trout were identified by tag, weighed, measured and released.

RESULTS AND DISCUSSION

Stream Utilization

Stream habitat sections were electrofished twice during the summer of 1988 (Table 1). The first sampling period, July 15-25, produced 65 brook trout weighing a total of 1797 g. The second period, August 4-14, produced a total of 74 trout which weighed 1452 g. The increase in trout abundance in August is primarily due to increased catches in small north-shore tributaries. This increased abundance is probably a function of trout having had more time to emigrate from the Nelson River into these streams by August. The effects of sampling too late in the season were noticed in 1986 when sampling at lower autumnal water temperatures produced fewer brook trout (Swanson and Kansas 1987). The reduced sample sizes in 1986 were attributed to the tendency for salmonids to "hide" in deep slower flowing water as water temperatures decrease (Gibson 1978).

Little overwintering is believed to occur in small north-shore streams (Conawapa Forebay) and trout must migrate out in fall. Recent studies may offer the mechanism by which juvenile brook trout escape small Conawapa Forebay tributaries before winter freeze up. Cunjak (1988) states that rapidly falling temperatures and increased flows during the autumn stress brook trout to the extent that they drift until they encounter a suitably deep, slow area. In the smallest Conawapa Forebay tributaries pools are lacking and trout may drift all the way to the Nelson River.

It has become apparent that the best sampling period is in mid

Table 1. Stream Electrofishing Data, 1988.

	1988											
	July 15-25						Aug. 4-14					
Section	Area (m^2)	Seconds	No. Trout	Wt. Trout (g)	CPUE (no./m^2/sec)	CPUE (g/m^2/sec)	Area (m^2)	Seconds	No. Trout	Wt. Trout (g)	CPUE (no./m^2/sec)	CPUE (g/m^2/sec)
M1	694	1739	3	77	0.000002485	0.000063801	776	1617	0	0	0	0
M2	735	1298	24	463	0.000025156	0.000485309	889	1639	22	492	0.000015098	0.000337663
M3	546	1300	19	516	0.000026768	0.000726965	569	1522	20	380	0.000023094	0.000438790
M4	716	1114	13	367	0.000016298	0.000460116	728	1269	9	214	0.000009742	0.000231643
B1	573	746	0	0	0	0	409	692	0	0	0	0
B2	360	282	0	0	0	0	257	326	1	4	0.000011935	0.000047743
B3	370	361	0	0	0	0	264	558	2	8	0.000013576	0.000054306
S1	686	1237	0	0	0	0	594	1058	0	0	0	0
S2	587	1151	0	0	0	0	680	1517	1	4	0.000000969	0.000003877
S3	658	1518	0	0	0	0	654	1523	0	0	0	0
T1	175	300	0	0	0	0	99	449	0	0	0	0
T2	195	337	0	0	0	0	190	693	2	16	0.000015189	0.000121515
G1	527	1317	0	0	0	0	536	1960	0	0	0	0
G2	384	1155	0	0	0	0	387	946	0	0	0	0
G3	714	997	0	0	0	0	614	1257	0	0	0	0
CN1	371	810	1	10	0.000003327	0.000033276	265	879	3	80	0.000012879	0.000343443
CN2	197	645	1	6	0.000007870	0.000047219	141	555	2	3	0.000025557	0.000038336
CN3	270	634	2	350	0.000011683	0.002044631	192	802	12	251	0.000077930	0.001630039
F1	—	—	-	—	—	—	160	674	0	0	0	0
F2	173	527	1	4	0.000010968	0.000043873	179	798	0	0	0	0
F3	257	877	1	4	0.000004436	0.000017747	282	769	0	0	0	0
BR1	501	498	0	0	0	0	505	659	0	0	0	0
BR2	600	556	0	0	0	0	605	821	0	0	0	0
BR3	627	778	0	0	0	0	627	705	0	0	0	0
Combined[a]	7920	14852	59	1423	5.0×10^{-7}	12.0×10^{-6}	7646	17026	57	1118	4.0×10^{-7}	8.5×10^{-6}

M = Moondance, B = Beaver, S = Swift, T = Tiny, G = Goose, CN = CN, F = Fifteen, BR = Brooks

a - excluding CN, Fifteen and Brooks Creeks data.

August, before water temperatures drop appreciably and trout drift out. Results will still vary from year to year and the absence of trout at one section during one sampling period should not be misconstrued as an indication of unsuitability for brook trout (eg. Tiny Creek Section 2; Table 1).

Data obtained during the August sampling period in 1988 were compared to data of previous years since August represents the best sampling period and it corresponds most closely with the periods sampled in 1986 and 1987. Trout catch per unit effort (CPUE) by frequency and weight is presented for streams combined into three categories: 1) Nursery - streams which serve primarily as nursery habitat for juvenile trout emigrating from the Nelson River (Beaver, Swift, Tiny, and Goose creeks), 2) Spawning - streams where appreciable spawning activity takes place (Moondance and CN creeks), and 3) Combined - both Spawning and Nursery streams included (Table 2, Figure 4). The data are most similar in 1987 and 1988. Lower CPUE in 1986 reflects sampling in cooler water of September when trout had already begun to emigrate from the small streams.

CPUE by frequency and weight was greatest in the spawning tributaries (Figure 4). CPUE by weight in 1986 was skewed by the presence of one large adult trout sampled near the spawning site in Moondance Creek (Figure 4). This CPUE is, therefore, not representative of the juvenile trout utilization level during the summer of 1986. CPUE varied least in the combined category, particularly for weight data.

The length-frequency distributions of brook trout sampled in

Table 2. Catch per unit of effort data for Conawapa Forebay tributary Electroshocking in 1986-88.

	1986 Sept. 11-Sept. 17	1987 Aug. 14-Sept. 14	1988 Aug. 4-Aug. 14	1988 July 15-July 25
	Frequency (no./m^2/sec) x 10^{-7}			
Nursery	0.9	1.0	1.0	0.0
Spawning	14.0[a]	39.0[b]	23.0	23.0
Combined	1.5[a]	6.0[b]	4.0	4.0
	Weight (g/m^2/sec) x 10^{-6}			
Nursery	7.7	3.7	0.6	0.0
Spawning	136.8[a]	51.8[b]	48.1	67.2
Combined	13.4[a]	9.0[b]	9.1	12.0

a - CN Creek Sections not sampled in 1986.
b - CN Creek Section 1 not sampled in 1987.
Nursery = Beaver, Swift, Tiny and Goose Creeks.
Spawning = Moondance and CN Creeks.

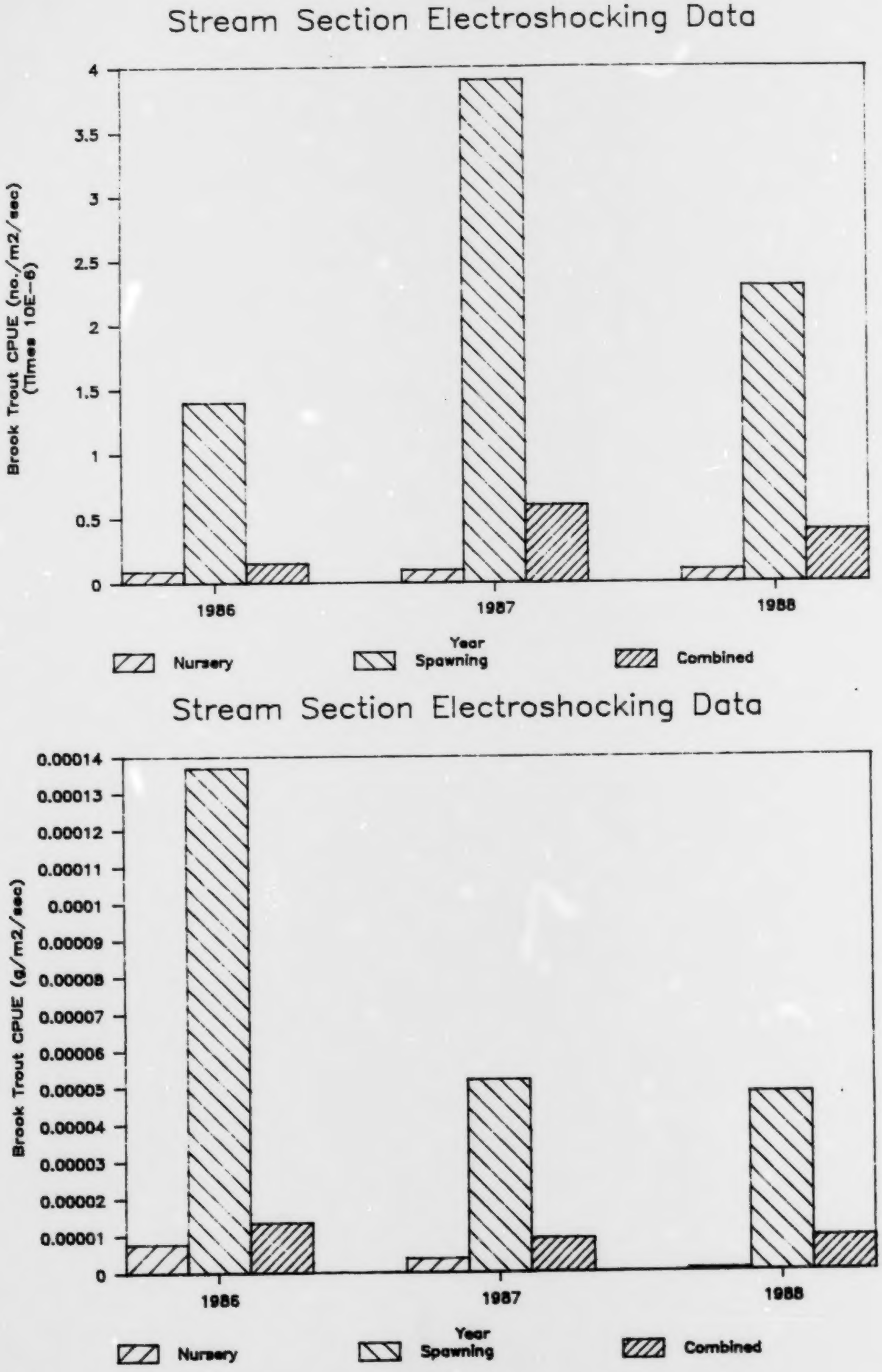


Fig. 4. Catch per unit effort data for nursery and spawning stream habitat in the Conawapa Forebay.

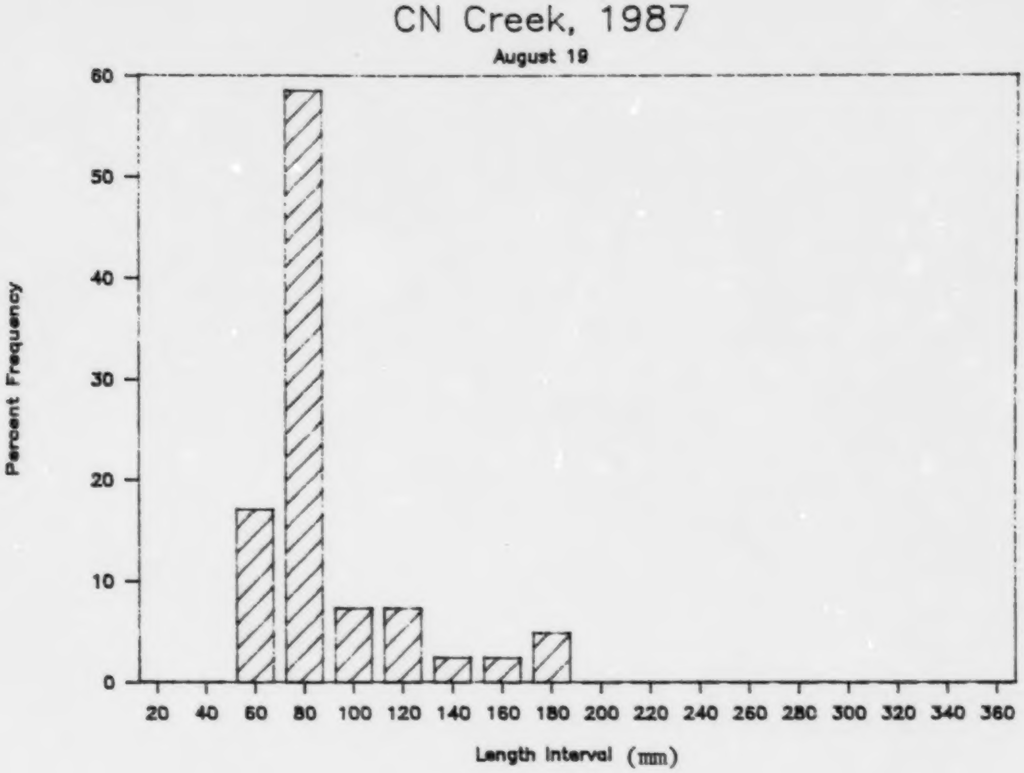
a 400 m section of CN Creek in 1987 and 1988 are presented in Table 3 and Figure 5. The data indicate that trout were slightly smaller in 1988. However, samples were collected earlier in August of 1988 than 1987 and trout would have had less time to grow. This is the likely cause of apparent differences.

Mark-recapture information indicate that half as many juvenile trout were using the lower reaches of CN Creek in 1988 as in 1987. It is estimated (Modified Schnabel Estimator) that 282 juvenile brook trout were present in 1988 while 652 were present in 1987 (Table 4). These results are believed to relate to the wash-out of the CN Creek road crossing during peak spring flows of 1988. Although the culverts had been installed with consideration for fish habitat, problems during the operational phase resulted in blockage through freezing. When the culverts froze shut the creek breached the berm to the CN gravel pit and flowed through the pit to the Limestone River. This diversion resulted in negligible flow in the lower reaches of CN Creek during the first two weeks of spring runoff. The low flows may have reduced available habitat such that brook trout were forced to disperse out of the stream to find suitable habitat elsewhere. When the culverts were opened the stream discharge at the downstream spawning site increased suddenly from 0.1 to 10.6 cubic meters per second. This drastic increase in flow would have ensured dispersal of young of the year brook trout out of the stream further reducing the population.

The additional electrofishing conducted on the small Nelson River tributary near Sundance revealed that this stream contained young of the year brook trout. A total of four trout were sampled

Table 3. CN Creek Brook Trout Length: Frequency Distributions; mark-recapture experiments, 1987-88.

1987			1988		
Length interval (mm)	Frequency	Percent frequency	Length interval (mm)	Frequency	Percent frequency
0–20	0	0.00	0–20	0	0.00
20–40	0	0.00	20–40	1	1.41
40–60	7	17.07	40–60	27	38.03
60–80	24	58.54	60–80	19	26.76
80–100	3	7.32	80–100	5	7.04
100–120	3	7.32	100–120	9	12.68
120–140	1	2.44	120–140	1	1.41
140–160	1	2.44	140–160	3	4.23
160–180	2	4.88	160–180	1	1.41
180–200	0	0.00	180–200	3	4.23
200–220	0	0.00	200–220	0	0.00
220–240	0	0.00	220–240	0	0.00
240–260	0	0.00	240–260	1	1.41
260–280	0	0.00	260–280	0	0.00
280–300	0	0.00	280–300	0	0.00
300–320	0	0.00	300–320	0	0.00
320–340	0	0.00	320–340	0	0.00
340–360	0	0.00	340–360	1	1.41



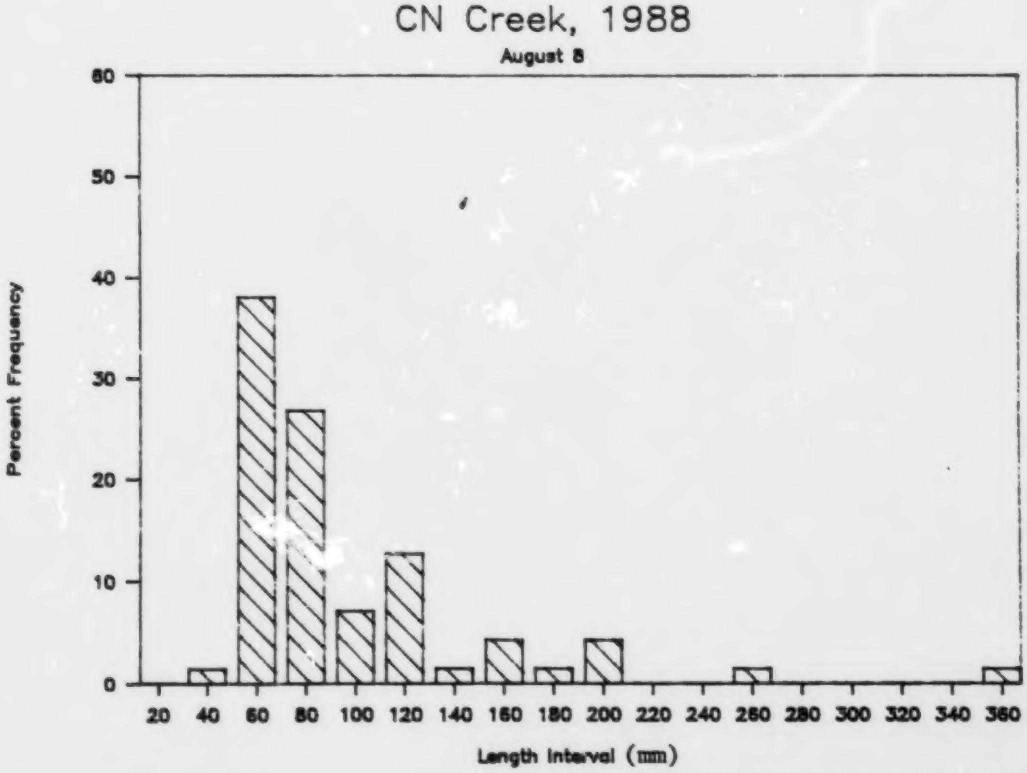


Fig. 5. Length-frequency distributions for brook trout electrofished in CN Creek in 1987 and 1988.

Table 4. Mark-recapture estimates and 95% confidence intervals for one 400 m long section of CN Creek in 1987 and 1988.

Year	Sample	Marks (M)	Total captures (C)	Recaptures (R)	Population estimate (N)	Confidence interval + (95%)
1987	Modified Petersen (29/08/87)	91	72	9	671	367–1328
	Modified Petersen (02/09/87)	91	93	13	617	371–1094
	Modified Schnabel (combined 87 data)	—	—	22	652	424–962
1988	Modified Petersen (10/08/88)	68	60	11	351	200–678
	Modified Petersen (29/08/88)	68	19	5	276	105–627
	Modified Petersen (30/08/88)	87	26	10	216	120–440
	Modified Schnabel (combined 88 data)	—	—	26	282	200–428

+ Confidence Intervals were obtained by assuming that recaptures (R) were Poisson in nature and using Ricker's (1975) confidence limits for Poisson variables.

in a cursory examination on September 9, 1988. These trout are believed to have originated from the Limestone River and immigrated into the creek. Since the stream does provide rearing habitat for juvenile trout, it was suggested that fish passage concerns be incorporated into the ongoing stream crossing repairs and that existing erosion be corrected.

Larval Drift

Numbers of larval trout captured each day are presented by study stream in Figures 6 and 7. In total 127 larval trout were sampled in 1988 drift traps. Catches in each stream were comparable to those of 1987. As in 1987 the largest number of larval trout were captured in CN Creek. In 12-Mile Creek only a few were captured in 1988 and none were captured in 1987. Catch per cubic meter of water flowing through the traps in each stream shows trends similar to those observed in frequency data (Figures 8 and 9), while the estimated total drift in each stream, calculated by extrapolating CPUE to total stream discharge, revealed a different pattern (Figures 10 and 11). The estimated total drift was considerably higher in the larger streams because of the much larger unsampled volume of flow. Consequently, the stream which had the greatest estimated larval drift was not CN Creek (trout sample size = 42, total estimated drift = 1,715 larval trout) but Sky Pilot Creek with a total estimated drift of 5,012 larval trout and a sample size of only 24.

The estimation of total trout drift is only accurate if larval trout are distributed randomly within the creek discharge. If fry

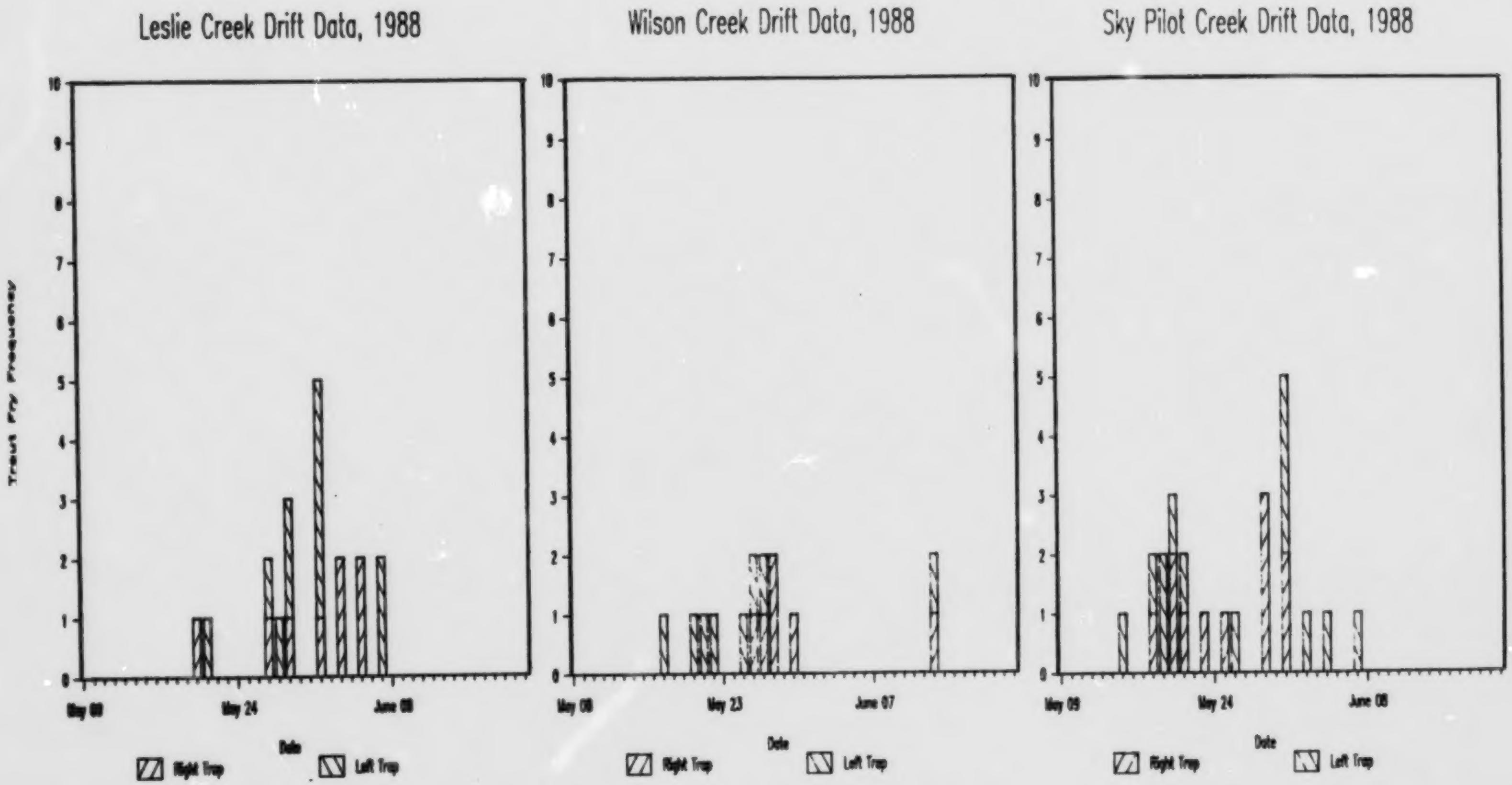


Fig. 6. Brook trout fry frequencies in Limestone Forebay drift traps, 1988.

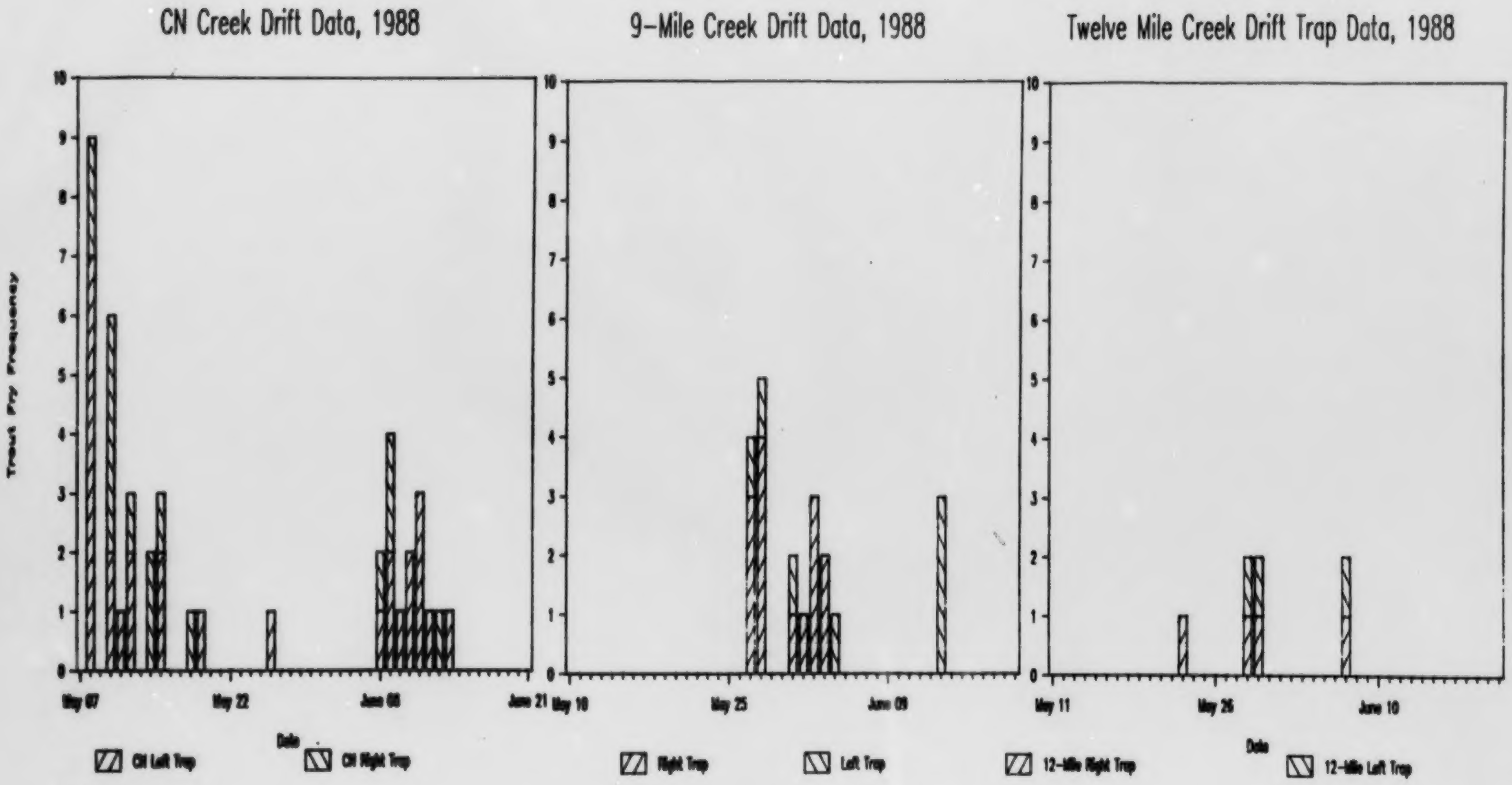


Figure 7. Brook trout fry frequencies in Limestone River drift traps, 1988.

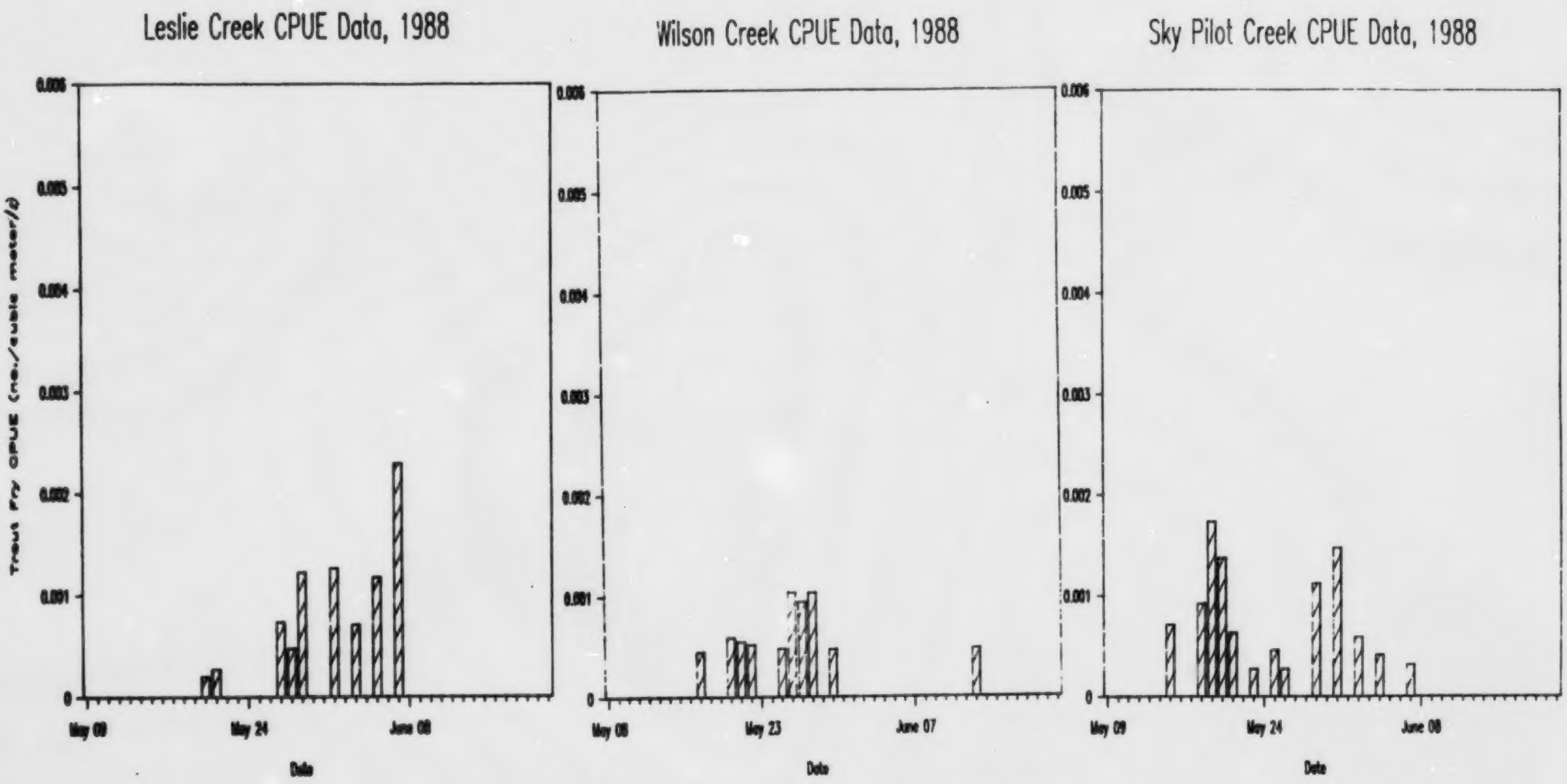


Fig. 8. Brook trout fry catch per unit effort in Limestone Forebay drift traps, 1988.

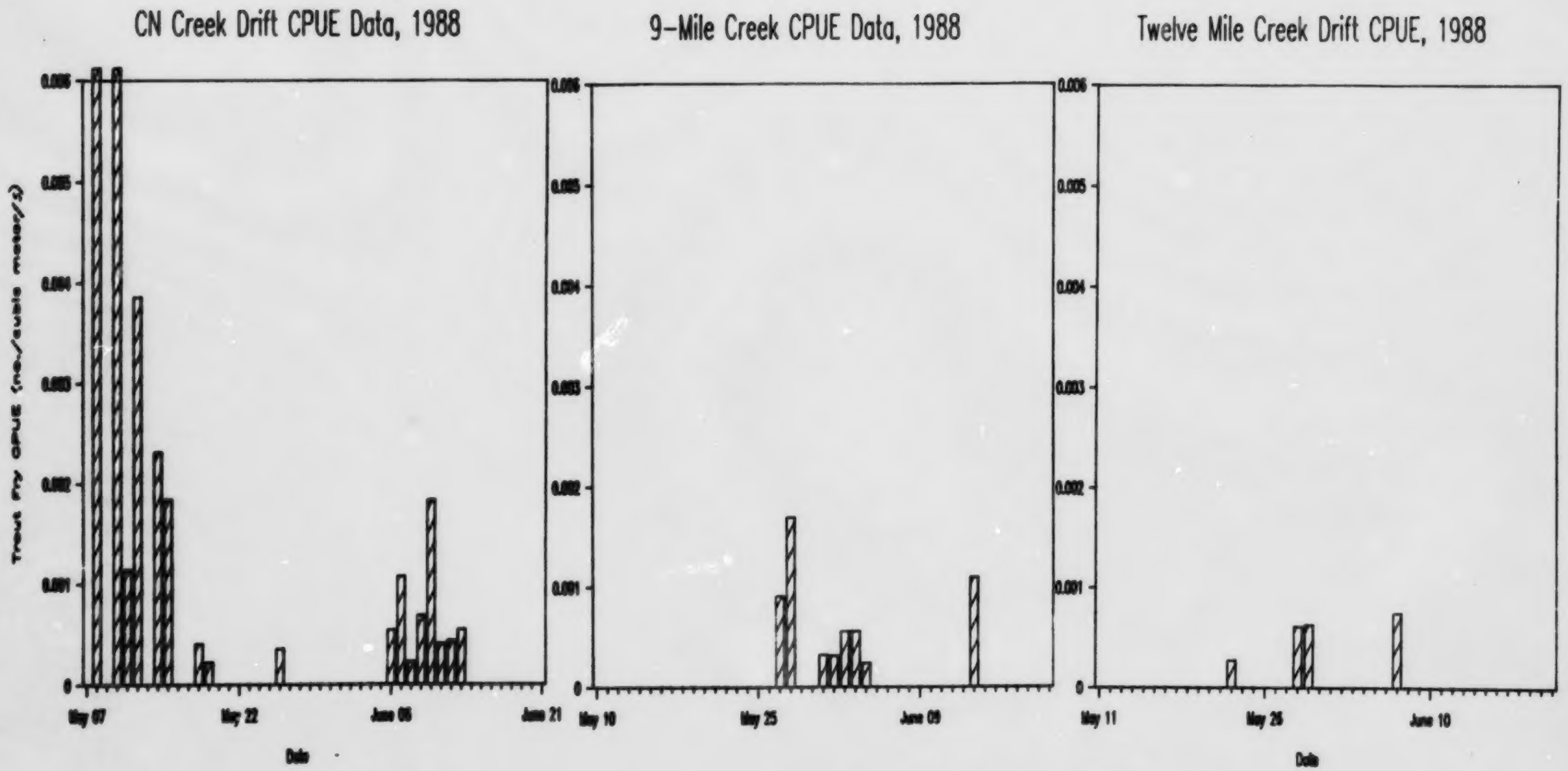


Figure 9. Brook trout fry catch per unit effort in Limestone River drift traps, 1988.

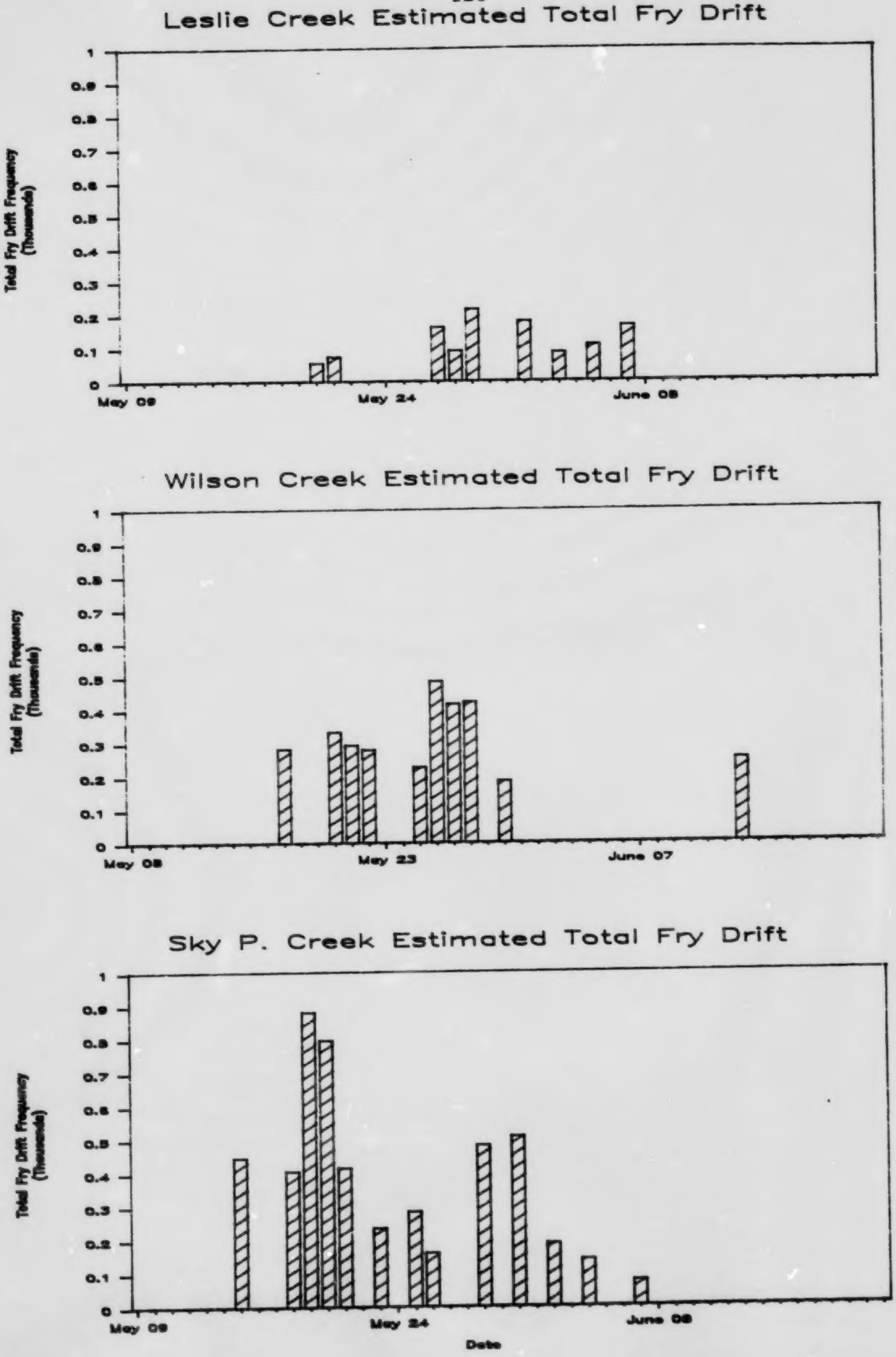
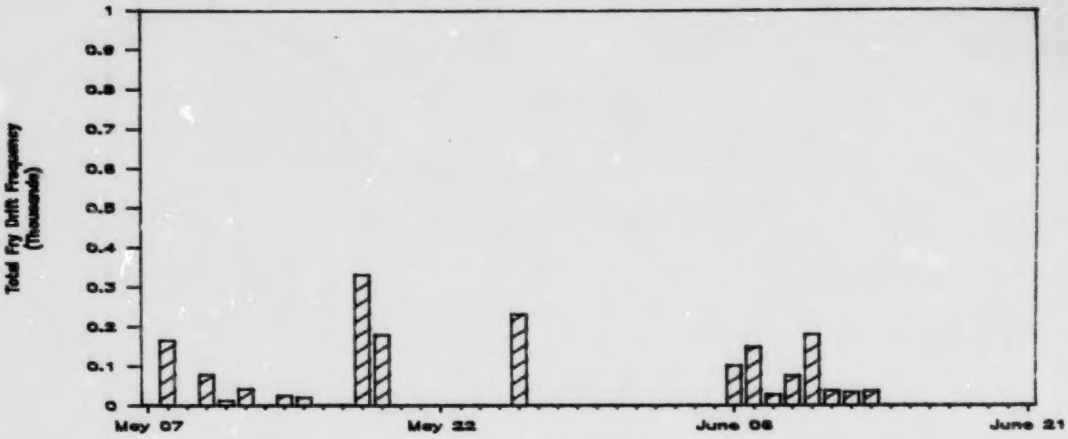
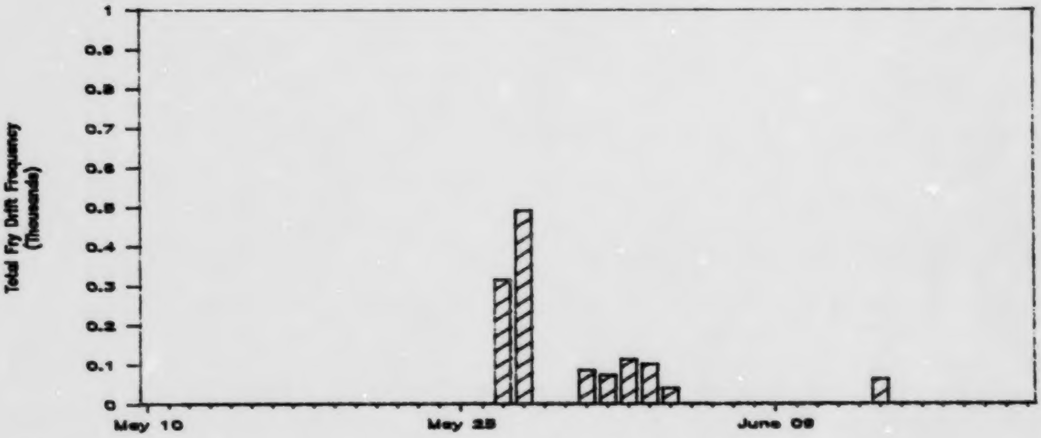


Fig. 10. Total trout fry drift at drift trap locations in Limestone Forebay study streams in 1988.

CN Creek Estimated Total Fry Drift



9—Mile Creek Estimated Total Fry Drift



12—Mile Creek Estimated Total Fry Drift

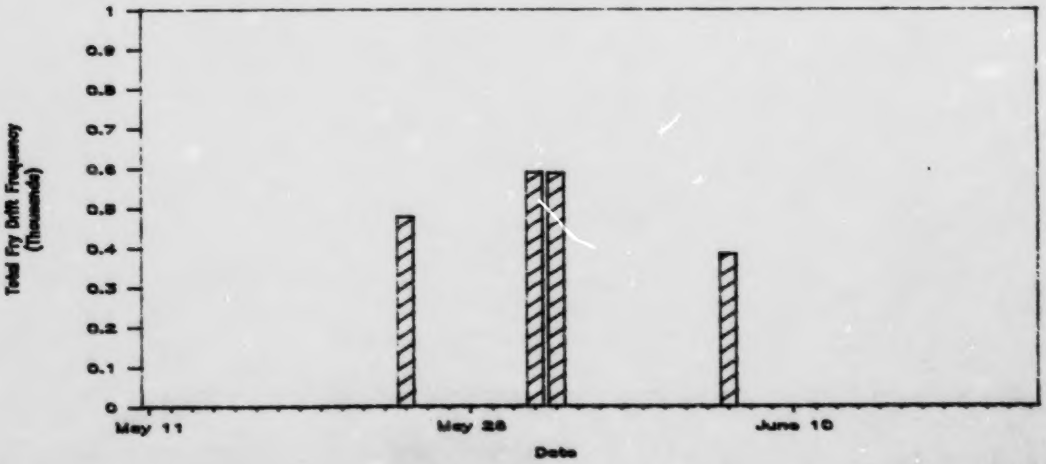


Fig. 11. **Total trout fry drift at drift trap locations in Limestone River streams in 1988.**

are aggregated in the fastest flows then the total drift will be underestimated because drift traps could not be placed in the fastest flows at peak spring discharges. If trout fry aggregate along the margin of the stream then the total drift will be overestimated because the faster flows, in this case where fewer fry drift, are not represented.

The two additional drift traps situated upstream of the monitoring site on Leslie Creek helped pinpoint the location of the spawning area. The most upstream trap sampled few trout larvae while the trap located closer to the highway crossing sampled as many trout fry as the downstream monitoring site. Inspection of the stream between the two upstream trap locations during the fall of 1988 revealed that brook trout spawn immediately upstream of the high water level of the Limestone Forebay. This area will be severely impacted through increased aquatic predator access to the trout spawning pool when the Limestone Forebay is flooded. Also, little cover will be available to fish in the inundated area of Leslie Creek because the trees were removed as part of Limestone Forebay development.

Temperature data for the six study streams during the drift sampling period are presented in Figures 12 and 13. The most noteworthy information obtained from these figures is the much warmer water temperatures in CN Creek in early May. While all the other streams were at or near 0°C, the water temperature in CN Creek was at or near 4°C. This was a consequence of the diversion of cold melt water through the CN gravel pit (when the culverts were frozen as described previously) leaving the downstream flow

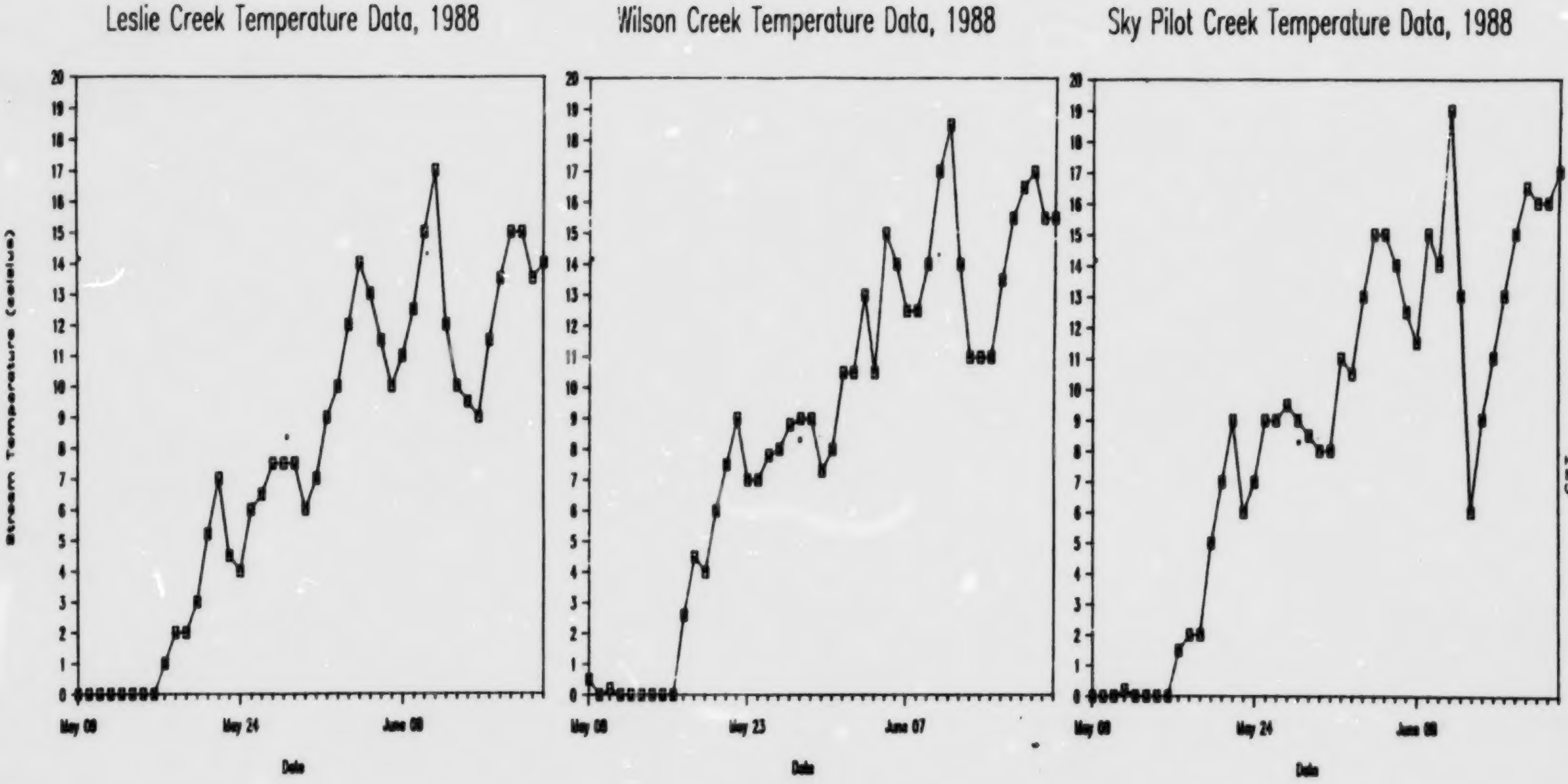


Fig. 12. Limestone Forebay stream temperatures during the 1988 drift sampling period.

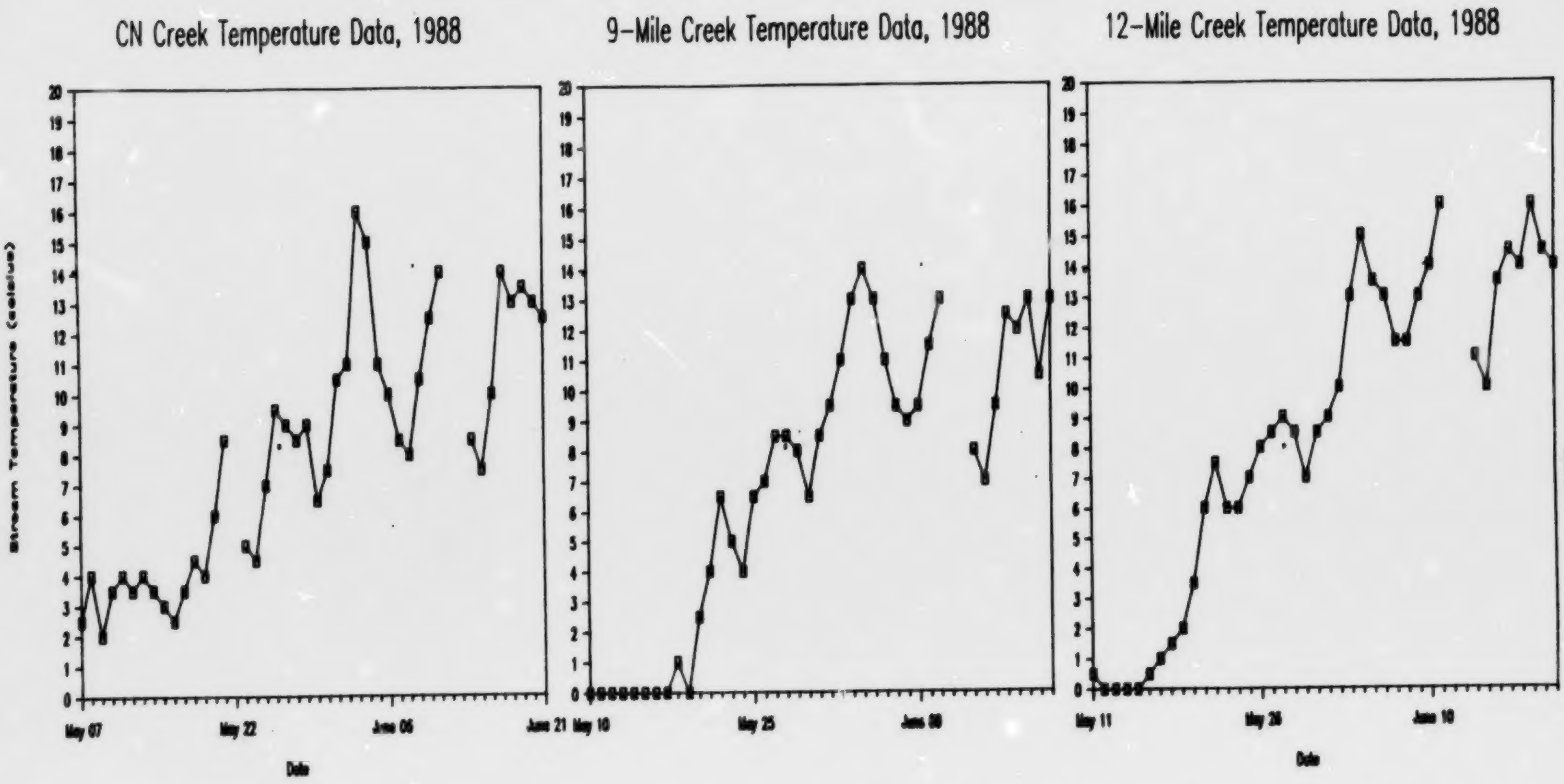


Fig. 13. Limestone River tributary temperatures during the 1988 drift sampling period.

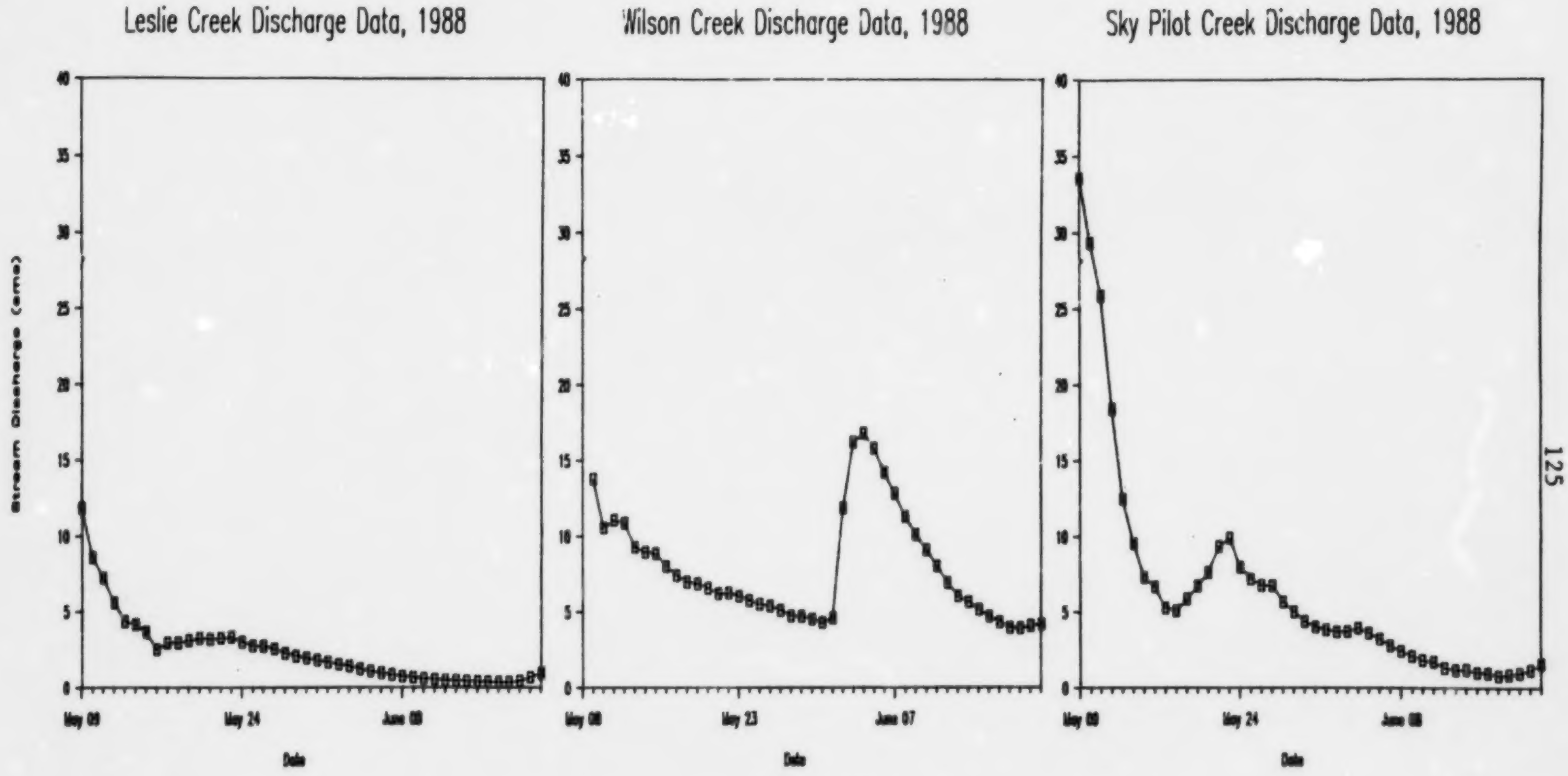


Fig. 14. Limestone Forebay stream discharges during the 1988 drift sampling period.

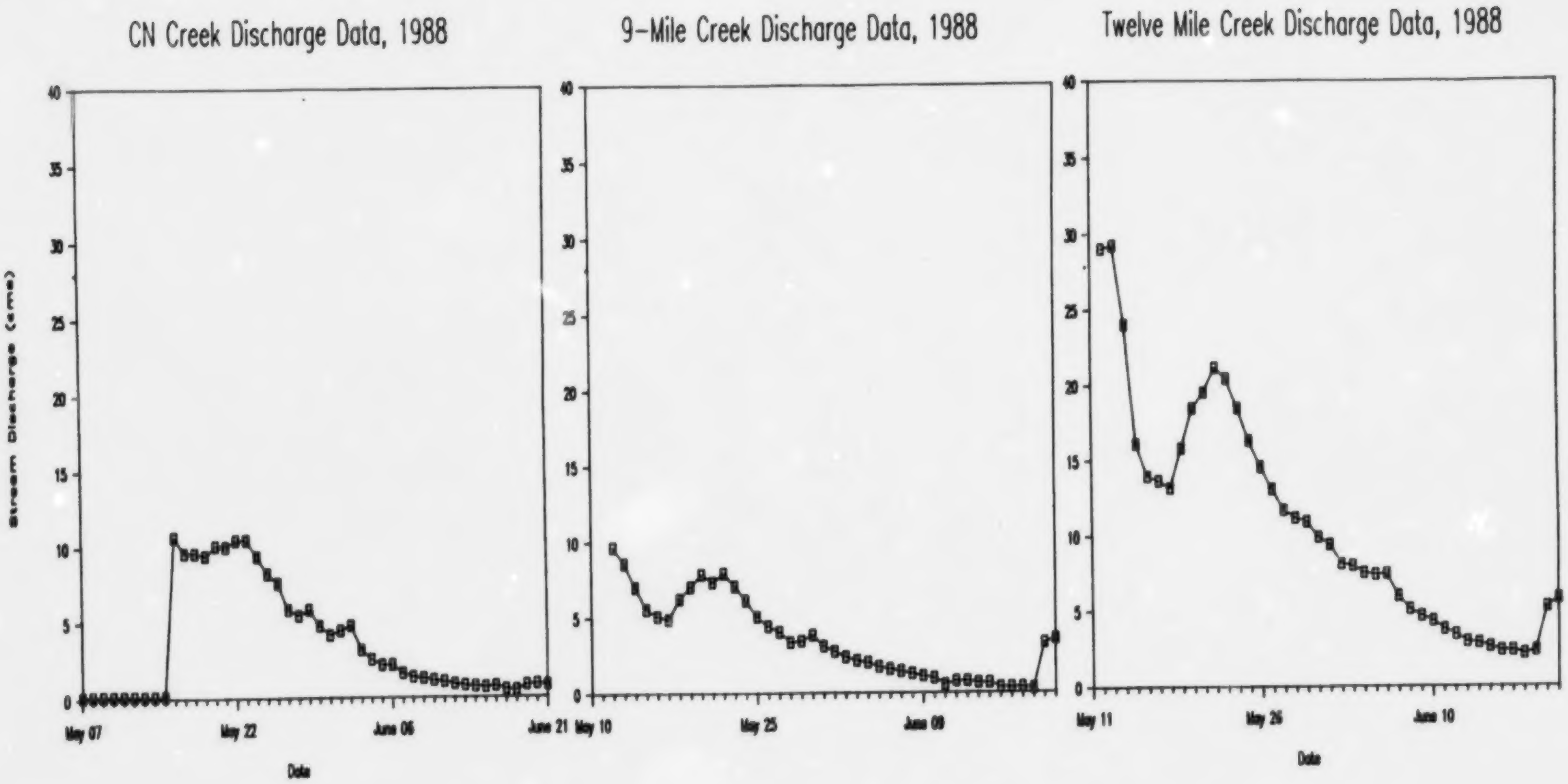


Fig. 15. Limestone River tributary discharges during the 1988 drift sampling period.

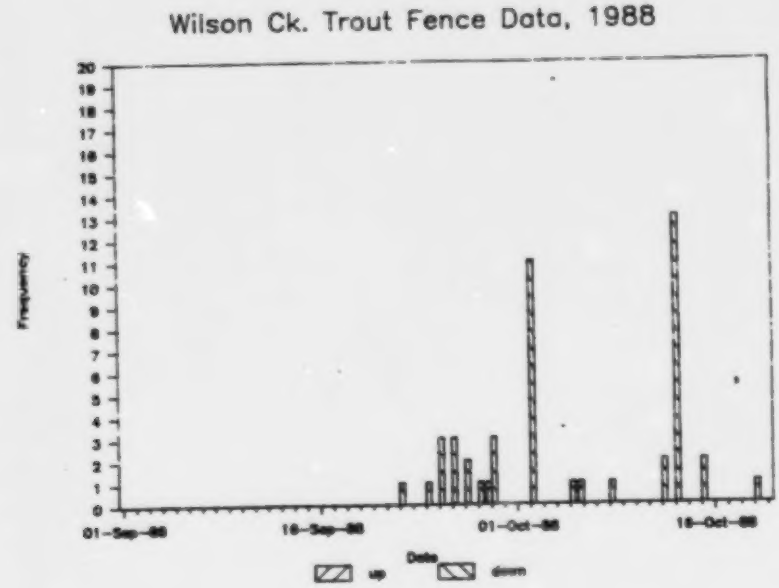
consisting, in good part, of warmer groundwater.

Discharge data are presented in Figures 14 and 15. Following initial high flows of spring freshet, discharge gradually declined through late May and early June of 1988. One exceptional event occurred in Wilson Creek between June 1 and 3 when discharge suddenly increased from approximately 5 cms to over 15 cms then slowly declined over the following week (Figure 14). This spate was likely the result of the sudden breakup of a beaver dam or ice jam upstream. It is uncertain whether the increase in flow affected larval drift or effectiveness of traps. No fry were captured in Wilson Creek during the high flow period while in the other Limestone Forebay streams fry continued to be collected (Figure 6).

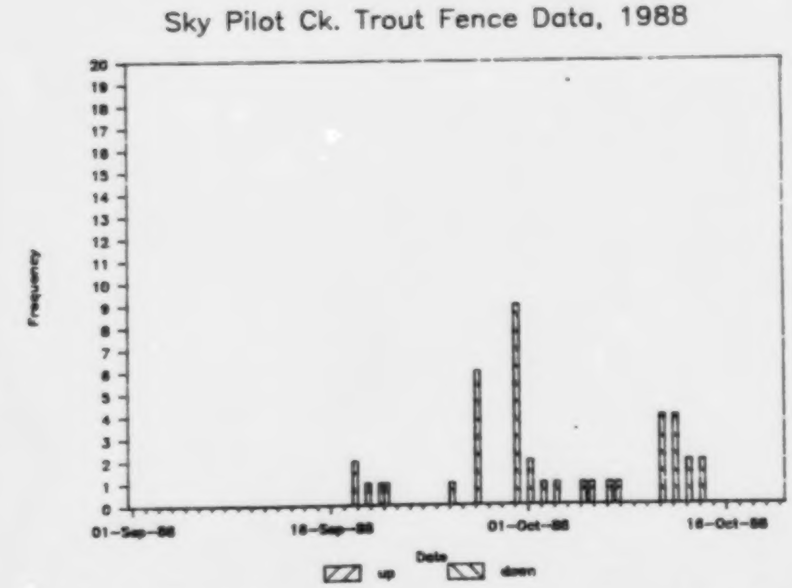
Spawning Population

Less discrete pulses of downstream movement by post-spawning brook trout were noted in 1988 than in 1987 (Figures 16-18). Perhaps the more gradual decline in temperatures in 1988 than in 1987 (Figures 19-21) decreased stress on trout and resulted in less passive downstream drift. Cunjak's (1988) work suggests that this might be a consequence of slower decline in water temperature. Daily weight of trout moving upstream and downstream in the fences is presented in Figures 22-24.

Comparisons of number and weight of brook trout moving downstream in each creek during the September-October sampling period in 1987 versus 1988 are presented in Table 5 and Figure 25. Downstream data are used for comparison because they best represent total numbers of adult trout spawning in these streams. Upstream

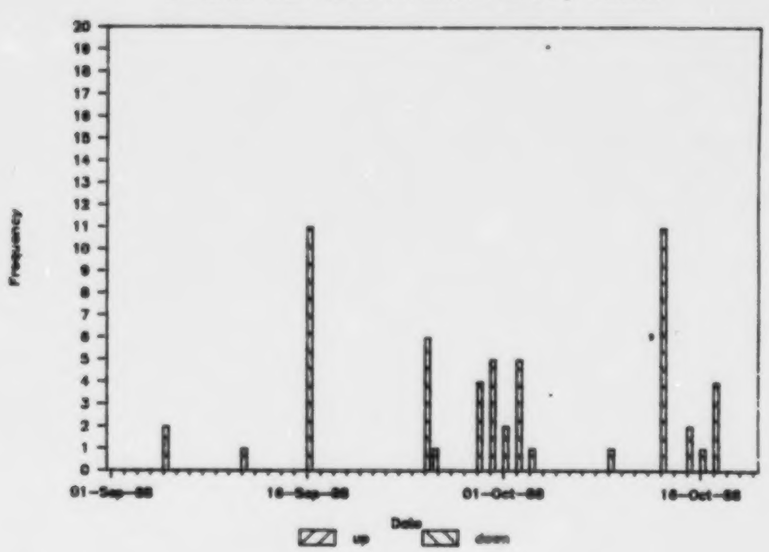


Wilson Ck. Trout Fence Data, 1988



Sky Pilot Ck. Trout Fence Data, 1988

Fig. 16. Daily frequencies of brook trout sampled moving upstream and downstream in Wilson and Sky Pilot Creeks fall fish fences in 1988.



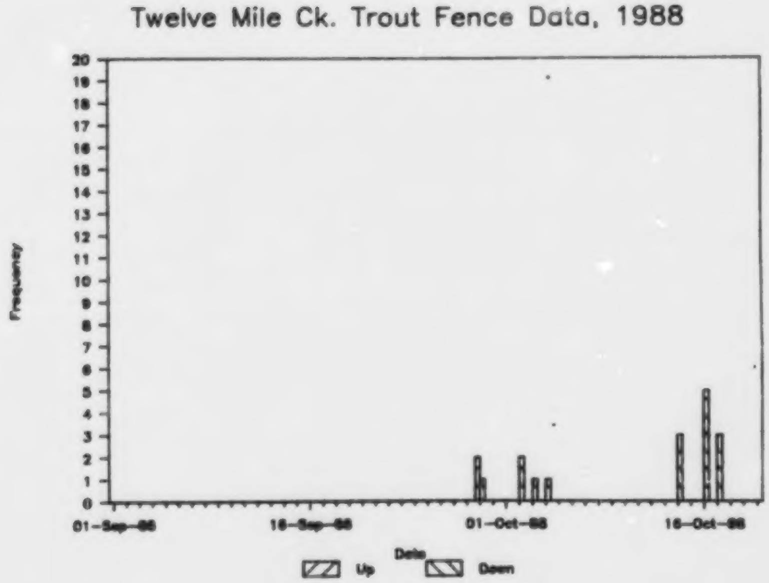


Fig. 17. Daily frequencies of brook trout sampled moving upstream and downstream in 9-Mile and 12-Mile Creeks fall fish fences in 1988.

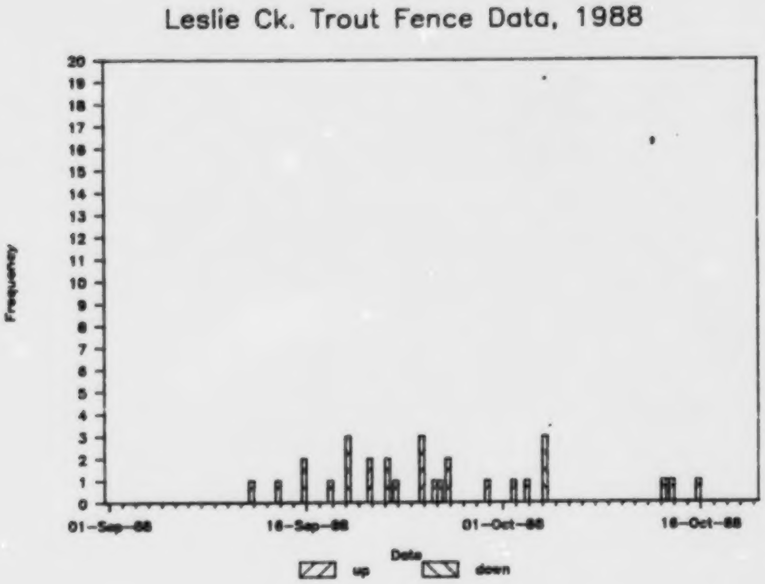
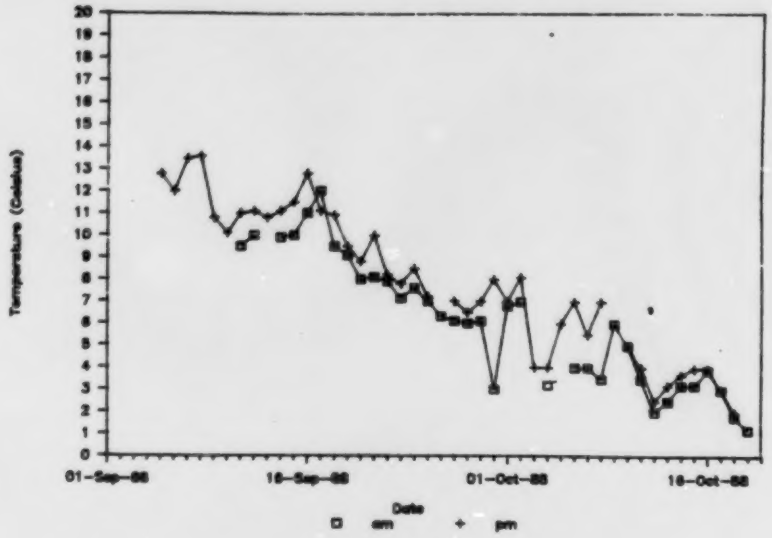

Leslie Ck. Trout Fence Data, 1988

Fig. 18. Daily frequency of brook trout sampled moving upstream and downstream in the Leslie Creek fall fish fence in 1988.

Wilson Ck. Temperature Data, 1988



Sky Pilot Ck. Temperature Data, 1988

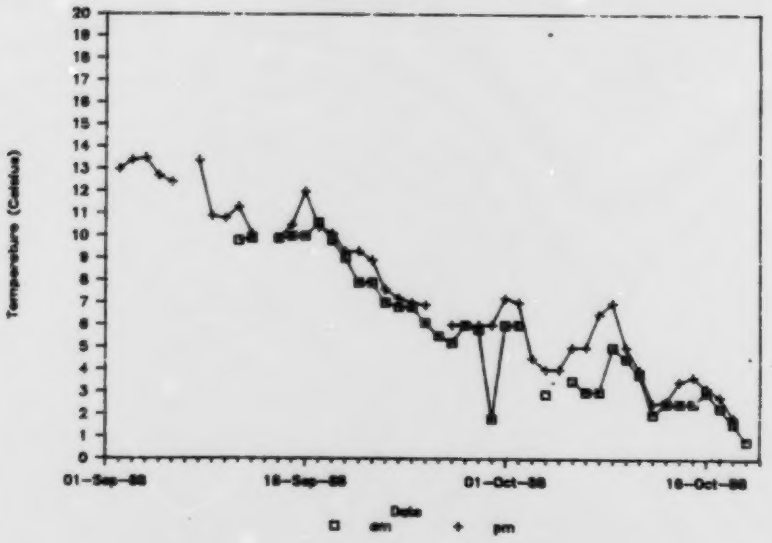
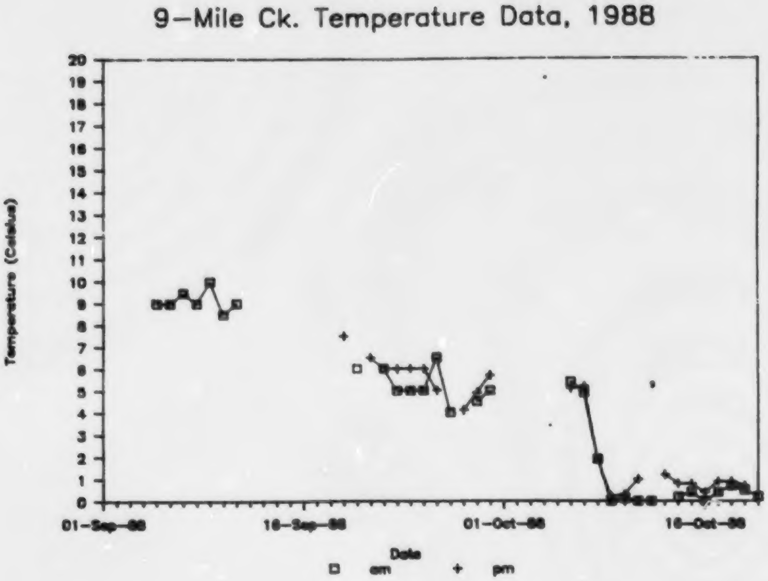


Fig. 19. Daily water temperatures in Wilson and Sky Pilot Creeks in the fall of 1988.



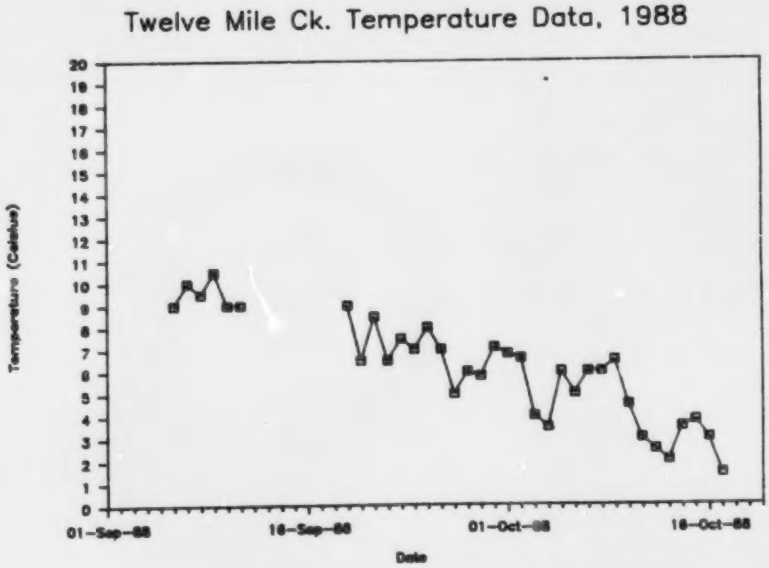


Fig. 20. Daily water temperatures in 9-Mile and 12-Mile Creeks in the fall of 1988.

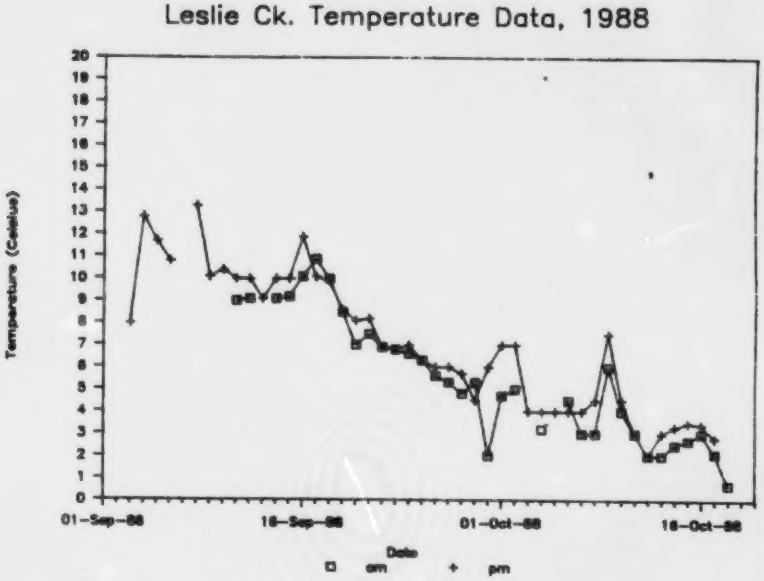
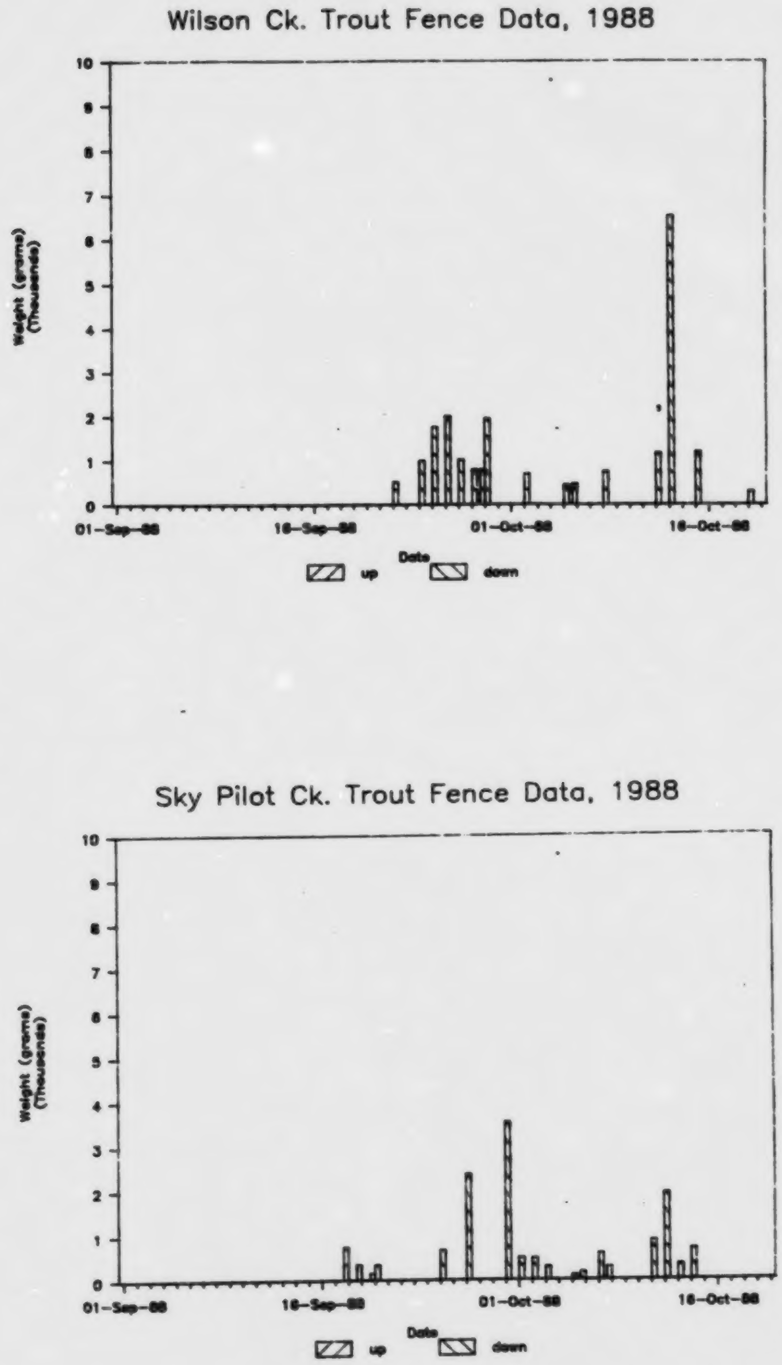


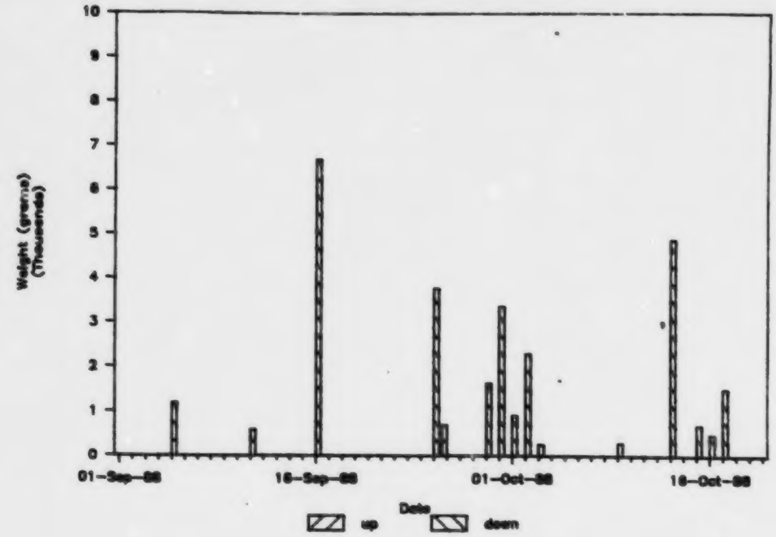
Fig. 21. Daily water temperatures in Leslie Creek in the fall of 1988.


Wilson Ck. Trout Fence Data, 1988

Sky Pilot Ck. Trout Fence Data, 1988

Fig. 22. Daily weights of brook trout sampled moving upstream and downstream in Wilson and Sky Pilot Creeks fall fish fences in 1988.

9–Mile Ck. Trout Fence Data, 1988



Twelve Mile Ck. Trout Fence Data, 1988

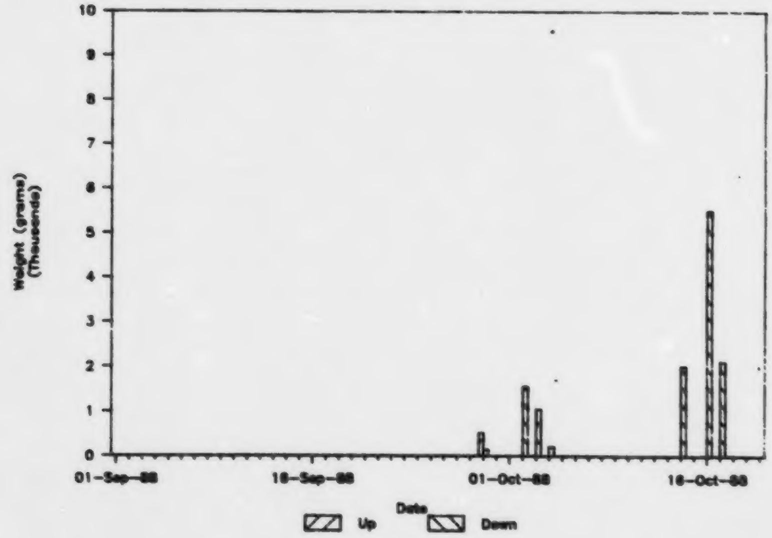


Fig. 23. Daily weights of brook trout sampled moving upstream and downstream in 9-Mile and 12-Mile Creeks fall fish fences in 1988.

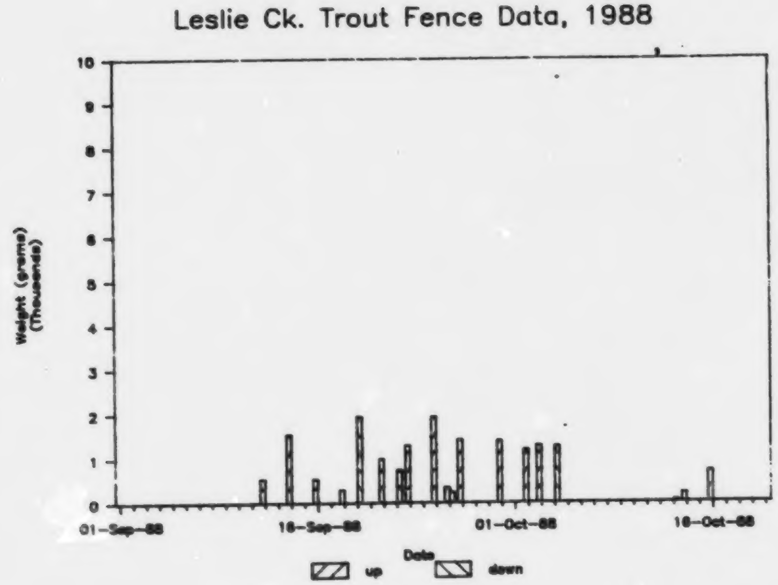
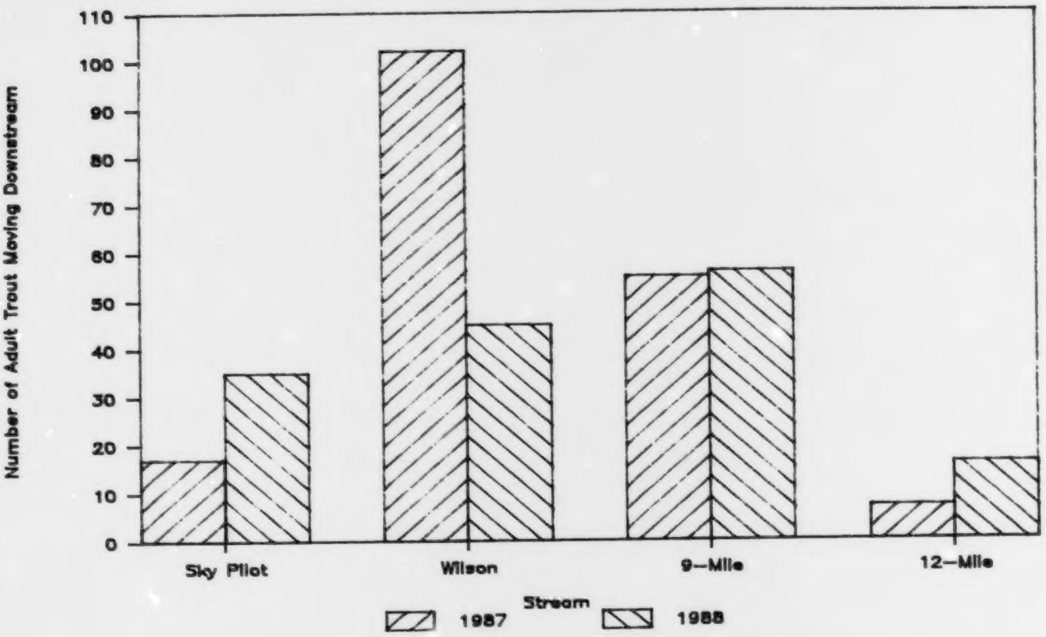


Fig. 24. Daily weights of brook trout sampled moving upstream and downstream in the Leslie Creek fall fish fence in 1988.

Table 5. Trout frequencies and weights sampled in upstream and downstream traps during the September - October periods of 1987-88.

	1987				1988			
	Frequency		Weight (g)		Frequency		Weight (g)	
Creek	up	down	up	down	up	down	up	down
Sky Pilot	7	17	4230	8570	6	35	1720	12870
Wilson	1	102	1600	42795	2	45	1275	20175
9-Mile	30	55	6540	19020	1	56	700	28735
12-Mile	4	7	2861	4585	2	16	520	12670
Leslie	-	-	-	-	19	10	13760	4255


Trout Fence Frequency Data, 1987–88.

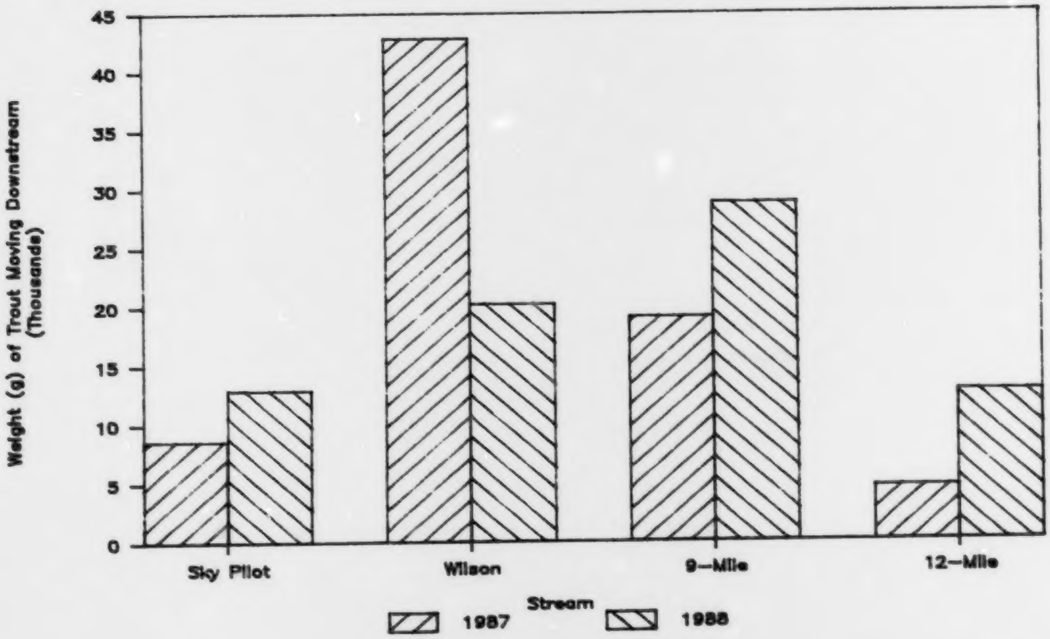

Trout Fence Weight Data, 1987–88.

Fig. 25. Brook trout frequency and weight data sampled moving downstream during the September - October period of 1987 and 1988 for Wilson, Sky Pilot, 9-Mile and 12-Mile Creeks.

data are incomplete since many adults will have migrated upstream prior to fence installation. All streams except Wilson Creek exhibited gains in both number and weight of trout sampled from 1987 to 1988. In 9-Mile Creek numbers caught were similar in both years while weight sampled was greater in 1988. This reflects growth and survival of individual trout in the population and consequently larger fish being sampled in 1988. This change has also been observed in a shift of the most abundant age group from two years old in 1987 to three in 1988 (Figure 26).

Wilson Creek catch declined in abundance and weight by 50% from 1987 to 1988 (Figure 25). The most abundant age group in Wilson Creek in 1988 was three years old (Figure 27), as it had been in 1987. The relative scarcity of four year old trout in 1988, despite the great preponderance of individuals three years old in 1987, suggests that a large number of that year class had been removed from the population. It is unlikely that this selective mortality was due to environmental conditions since no major habitat disruptions had occurred and no corresponding declines in population were observed in other streams. The large decrease was most likely due to angler harvest of brook trout at the mouth of Wilson Creek in spring of 1988. It appears that trout which moved downstream in the fall of 1987 staged at the creek mouth in spring of 1988 before moving back upstream. Local anglers caught many of these trout. Tag returns and anecdotal information indicate that the harvest rate was high.

Age-frequency distributions for other streams included in spawning investigations are presented in Figures 26-28. The Leslie

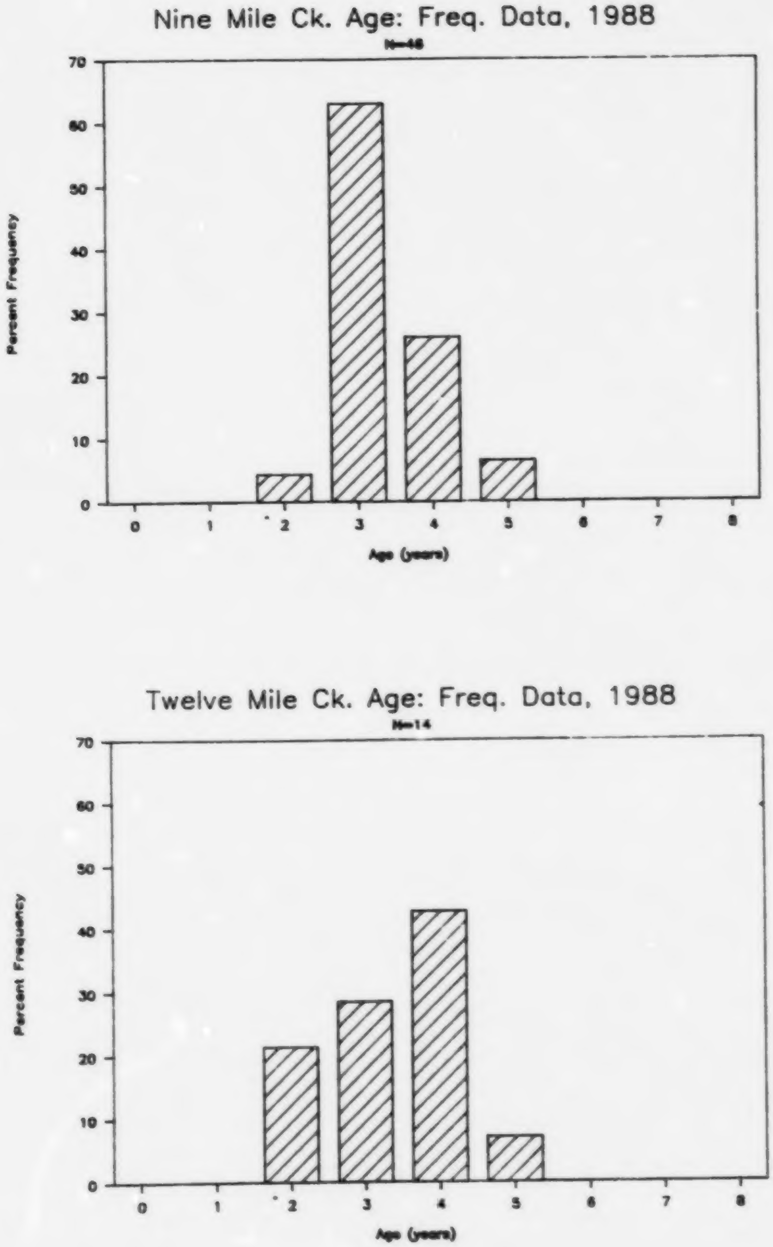
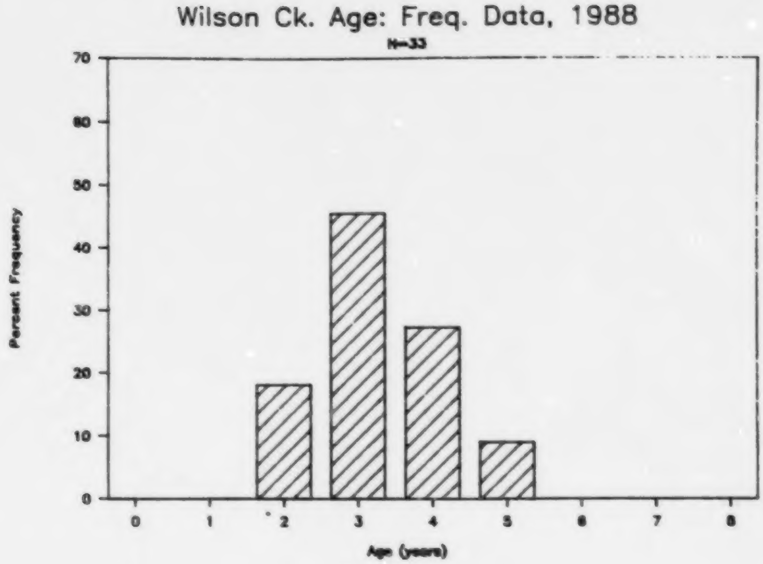
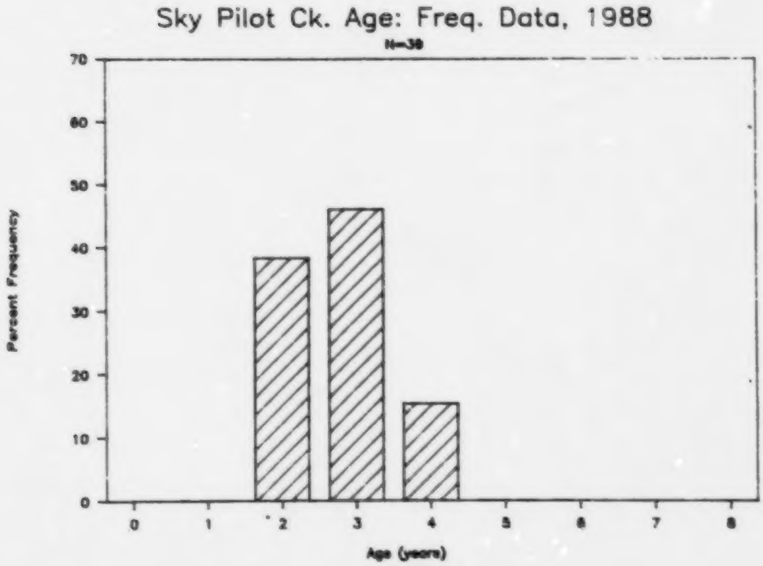


Fig. 26. Age-frequency distributions for brook trout sampled in 9-Mile and 12-Mile Creeks fish fences in 1988.



Wilson Ck. Age: Freq. Data, 1988



Sky Pilot Ck. Age: Freq. Data, 1988

Fig. 27. Age-frequency distributions for brook trout sampled in Wilson and Sky Pilot Creeks fish fences in 1988.

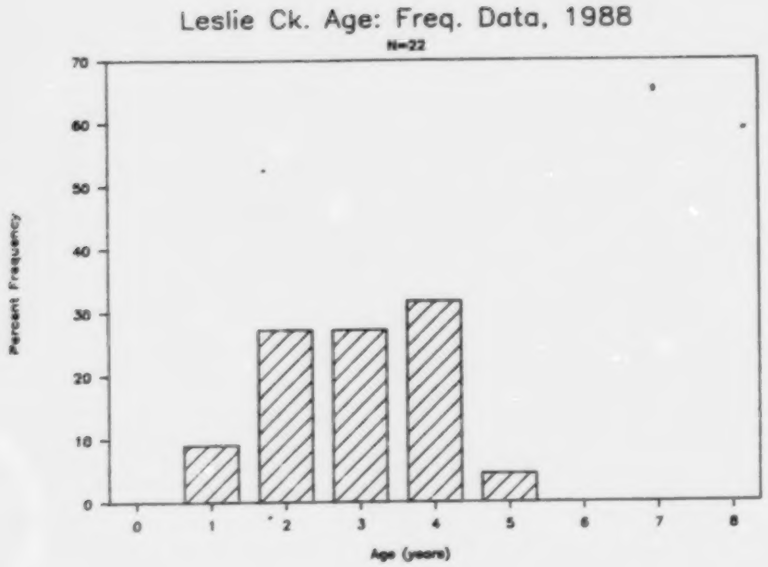


Fig. 28. Age-frequency distribution for brook trout sampled in the Leslie Creek fish fence in 1988.

Creek age-frequency distribution for 1988 (Figure 28) indicates that the age structure of this population includes a large proportion of older trout; the most abundant age group was four years old and the three year old group was as abundant as the two year old group. This may indicate lighter angling pressure than in areas such as Wilson Creek.

Length-frequency distributions are presented for all study streams in Figures 29-31. Generally, 1988 distributions were similar to those of 1987. The length distribution of Wilson Creek trout changed only slightly, reflecting the maintenance of three year old trout as the most abundant year class. In 9-Mile Creek, length frequency shifted such that there was a greater percentage of larger fish in 1988 than in 1987. This illustrates growth of the large two year old class in 1987 to three years old in 1988 as described above.

Strontium analysis of fin samples indicated that 1 of 151 newly captured trout had spent some time in the marine conditions of Hudson Bay (i.e. strontium level greater than 215 ug/l). Recaptured trout were not re-sampled for strontium level determination. The level of anadromy, 0.7%, is similar to that determined in previous years.

Floy Tagging

Two hundred and sixty seven brook trout over the length of 17 cm were floy tagged and released during the 1988 field season. The distribution of tags for the years 1985-88 is presented in Table 6. A summary of 1988 recapture information is presented in Table 7 and

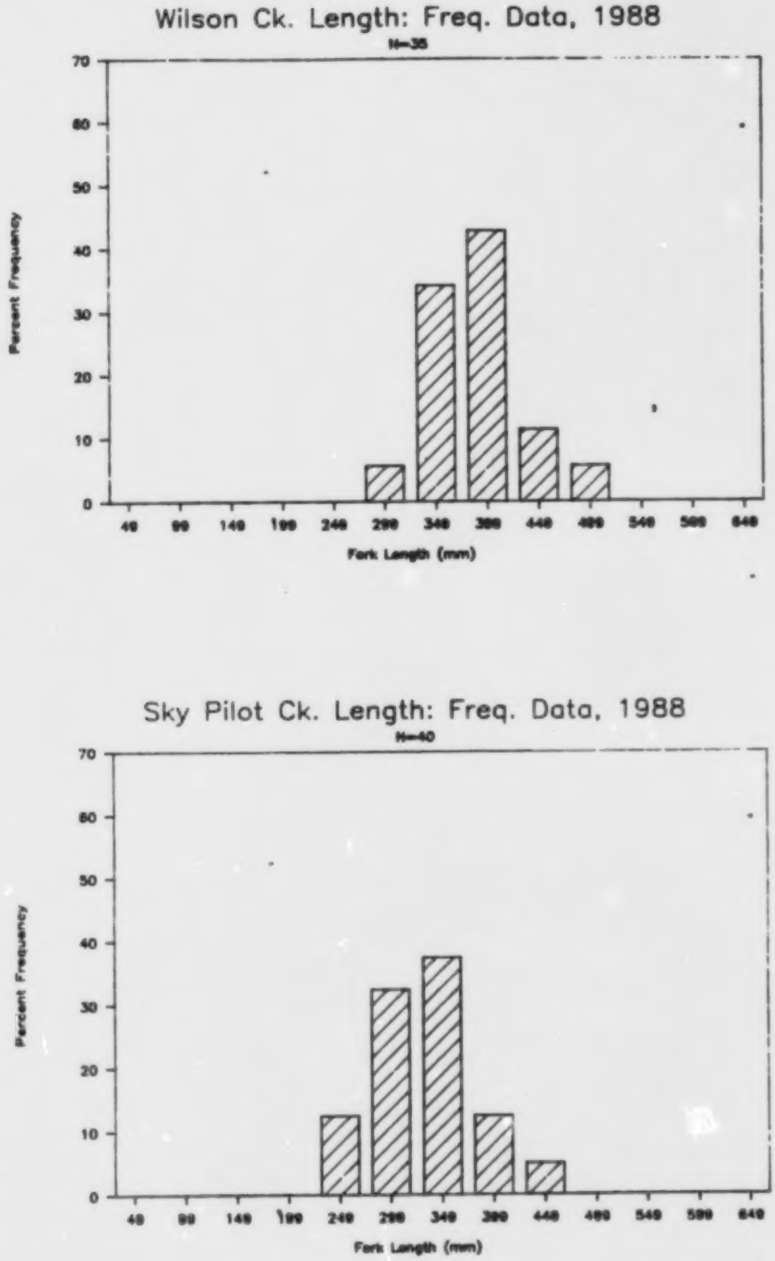


Fig. 29. Length-frequency distributions for brook trout sampled in Wilson and Sky Pilot Creeks fish fences in 1988.

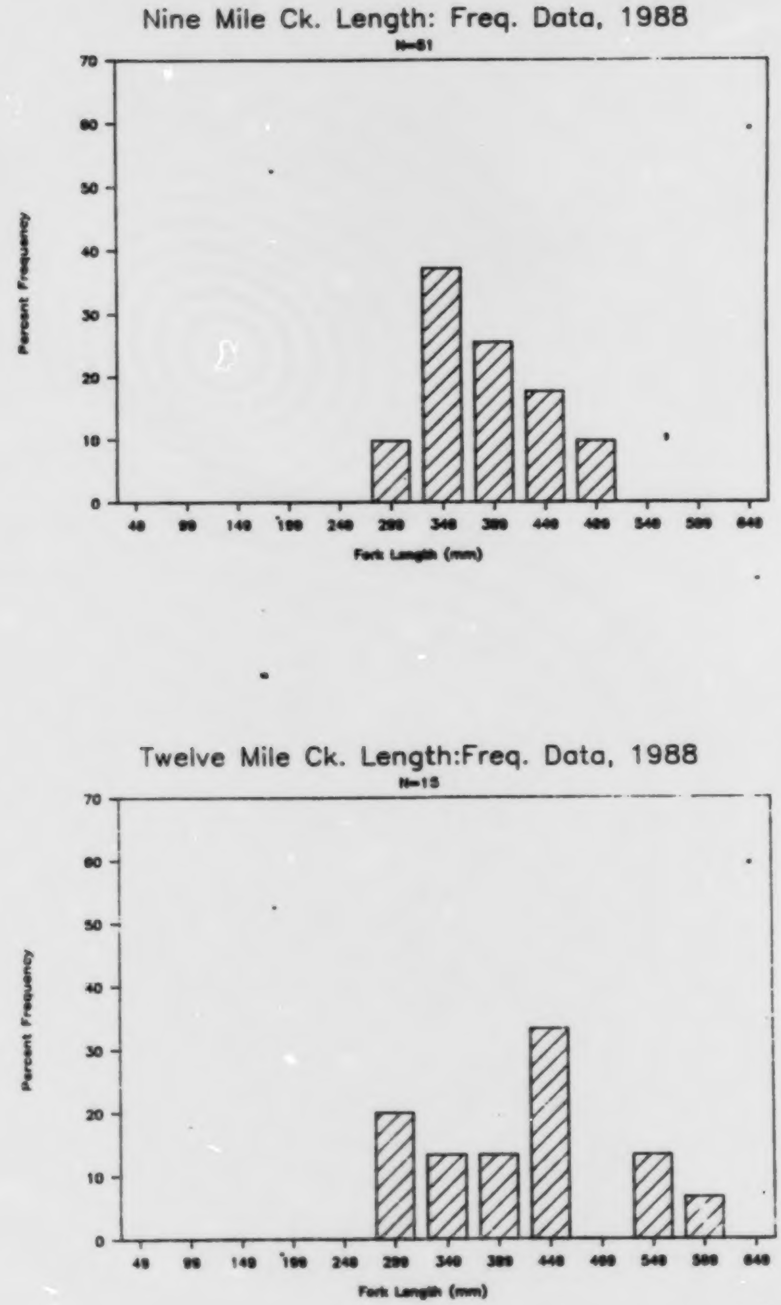


Fig. 30. Length-frequency distributions for brook trout sampled in 9-Mile and 12-Mile Creeks fish fences in 1988.

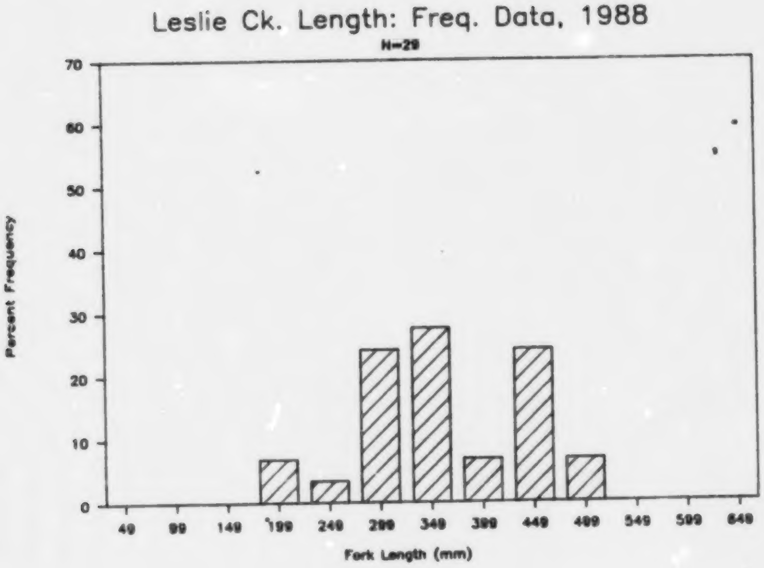


Fig. 31. Length-frequency distribution for brook trout sampled in the Leslie Creek fish fence in 1988.

Table 6. Number of brook trout tagged in study streams by year.

Location	1985	1986	1987	1988	Total
Limestone R.	29	14	7	17	67
9-Mile Ck.	28	4	59	51	142
12-Mile Ck.	5	0	21	16	42
CN Ck.	2	0	71	16	89
Bird Ck.	2	0	0	0	2
Sky Pilot Ck.	83	0	25	39	147
Wilson Ck.	7	0	99	34	140
Leslie Ck.	0	1	0	28	29
Moondance Ck.	41	4	61	8	114
Sundance Ck.	2	0	0	0	2
Beaver Ck.	0	0	2	0	2
Swift Ck.	4	0	0	0	4
Weir R.	0	35	0	23	58
French Ck.	0	0	0	6	6
McMillan Ck.	0	0	0	2	2
Gods R.	0	0	0	27	27
Total	203	58	345	267	873

Table 7. Summary of new tags in 1988, recaptures of 1988 tags and recaptures of tags from previous years (1985-87) in 1988.

Location	New Tags	1988 Tags Recaptured	1985-87 Tags Recaptured
Limestone R.	17	0	0
9-Mile Ck.	51	1	10
12-Mile Ck.	16	1	5
CN Ck.	16	5	2
Sky Pilot Ck.	39	1	0
Wilson Ck.	34	0	1
Leslie Ck.	28	0	0
Moondance Ck.	8	0	0
Weir R.	23	1	1
French Ck.	6	0	0
McMillan Ck.	2	0	0
Gods R.	27	0	0

the tagging history of each recaptured brook trout is presented in Appendix 8. Table 8 presents a summary of trout recaptured in each study stream as a percentage of total number tagged in the stream of origin. Recaptures were included only if a significant move had occurred: 1) from one stream to another, or 2) if a fish was recaptured in the same stream as it was tagged, a sufficient period of time must have elapsed since release to allow dispersal. The second consideration is most important when considering fish captured travelling upstream to spawn and again when travelling downstream following spawning. Such recaptures were not included in this analysis. The results indicate that as expected the greatest percentage of recaptures occurred in the same streams where the fish had been tagged. However, notable percentages of recaptures occurred in streams near those where the trout were tagged (eg. recaptures in 12-Mile Creek of fish which were tagged in 9-Mile Creek) and some trout have even been recaptured in streams far from the location of tagging (eg. recapture of a fish in Wilson Creek which had been tagged in 9-Mile Creek; recapture of a fish in Moondance Creek which had been tagged in the Limestone River). This information illustrates that Nelson River brook trout use the system opportunistically providing potential for mixing of stocks from one stream to another.

Recapture Location

Tagging Location

# / %	W	12	9	CN	M	L	We	B	Sk
W	5 / 3.6								1 / .7
12		4 / 9.5							
9	1 / .7	1 / .7	15 / 10.6			1 / .7			
CN									
M					2 / 1.8	1 / .9			
L		1 / 1.5	4 / 6			6 / 9			
We							1 / 1.7		
B						1 / 50			

W-Wilson,12-12Mile,9-9Mile,CN-CN Creek,M-MoondanceL-Limestone,We-Weir,B-Bird,Sk-Sky Pilot

Table 8. Summary of trout recaptured in each study stream as a percentage of total tagged in stream of origin, 1985-1988.

CONCLUSIONS

1. Summer rearing habitat for juvenile brook trout includes both spawning streams and smaller tributaries not used for spawning. Spawning streams harbour more juveniles than the smaller "nursery" streams along the north shore of the Conawapa Forebay. Juveniles do not overwinter in these small tributaries but migrate out in fall.

2. The population of brook trout rearing in CN Creek during the summer of 1988 was half the size of that in 1987. This reduction is believed to have been due to frozen culverts at the CN Creek road crossing which first reduced flows downstream in spring decreasing available habitat, then once opened, produced a flushing flow which would have washed more fish from the stream.

3. The small unnamed Nelson River tributary near the town of Sundance serves as a brook trout rearing stream. The Fisheries Branch was requested by Manitoba Hydro to investigate this stream as stream-crossing repairs were planned. Since the stream does harbour trout it is important that fish habitat concerns be considered relative to stream crossing activities.

4. Numbers of larval brook trout captured in drift traps in 1988 were comparable to 1987.

5. The brook trout spawning area in Leslie Creek has been identified at a point just above the calculated high water level of the Limestone Forebay. Flooding of the forebay will allow access by predators such as northern pike to the spawning area. In addition, little cover will be available to fish in the inundated area of Leslie Creek because trees were removed as part of Limestone Forebay development.

6. Spawning populations in study streams have increased slightly or remained constant between 1987 and 1988, with the exception of Wilson Creek. The population in Wilson Creek in 1988 was only half as large as in 1987. The decrease is believed to be a result of high angler harvest in spring of 1988.

7. Incidence of anadromous trout in the study streams in 1988 was estimated as 0.7%, which is similar to that determined in previous years.

8. Recaptures of tagged fish indicate that brook trout use habitat in the Nelson River system opportunistically providing potential for mixing of stocks among streams.

RECOMMENDATIONS

1. Consideration should be given to requirements of fish during planning, construction and operation of developments near streams to ensure that habitat is maintained in suitable condition. The washout of the CN Creek road crossing due to operational difficulties illustrates the severity of damage which can occur to trout populations. In the case of repair of the stream crossing over the unnamed stream near Sundance it was recommended that fish passage be provided, existing erosion problems be corrected and no further sediment be added to the stream.

2. Floating drift traps should be used in conjunction with currently used fixed traps to sample fry drift in fastest stream flows. This will help determine whether spatial distribution of larvae is random within flow and whether estimates of total drift are accurate.

3. The brook trout population in Wilson Creek can be significantly impacted by angler harvest in a single year. Efforts should be made to ensure that harvest is maintained within the legal limit of one fish per day. Visits to popular angling sites by enforcement officers should be a priority.

PART VI

LAKE STURGEON TELEMETRY - ANGLING LAKE

PART VI

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INTRODUCTION

Twenty-two percent of sturgeon tagged in the lower Nelson River in 1986 showed a tendency to reside, at least partially, in Angling Lake (Figure 1). Data indicated that movement from the Nelson River into Angling Lake occurred sometime in May or June of 1987, when the Angling River water levels were highest (Swanson et al.1988). This could indicate a spawning migration. A number of sturgeon were caught in gill nets throughout Angling Lake during a fisheries inventory in the summer of 1987 (Swanson et al.1988). However, data allow only speculation on the reasons for sturgeon inhabiting Angling Lake.

In order to assess the importance of Angling Lake to the lower Nelson River sturgeon stocks a radio telemetry project was initiated in 1988. The objectives of the study were to: 1) tag 10 sturgeon with 2-3-year life expectancy radio transmitters in Angling Lake, and 2) through the monitoring of these tags over the course of their life span, attempt to define the timing and extent of sturgeon movements in and out of the Angling Lake/River system.

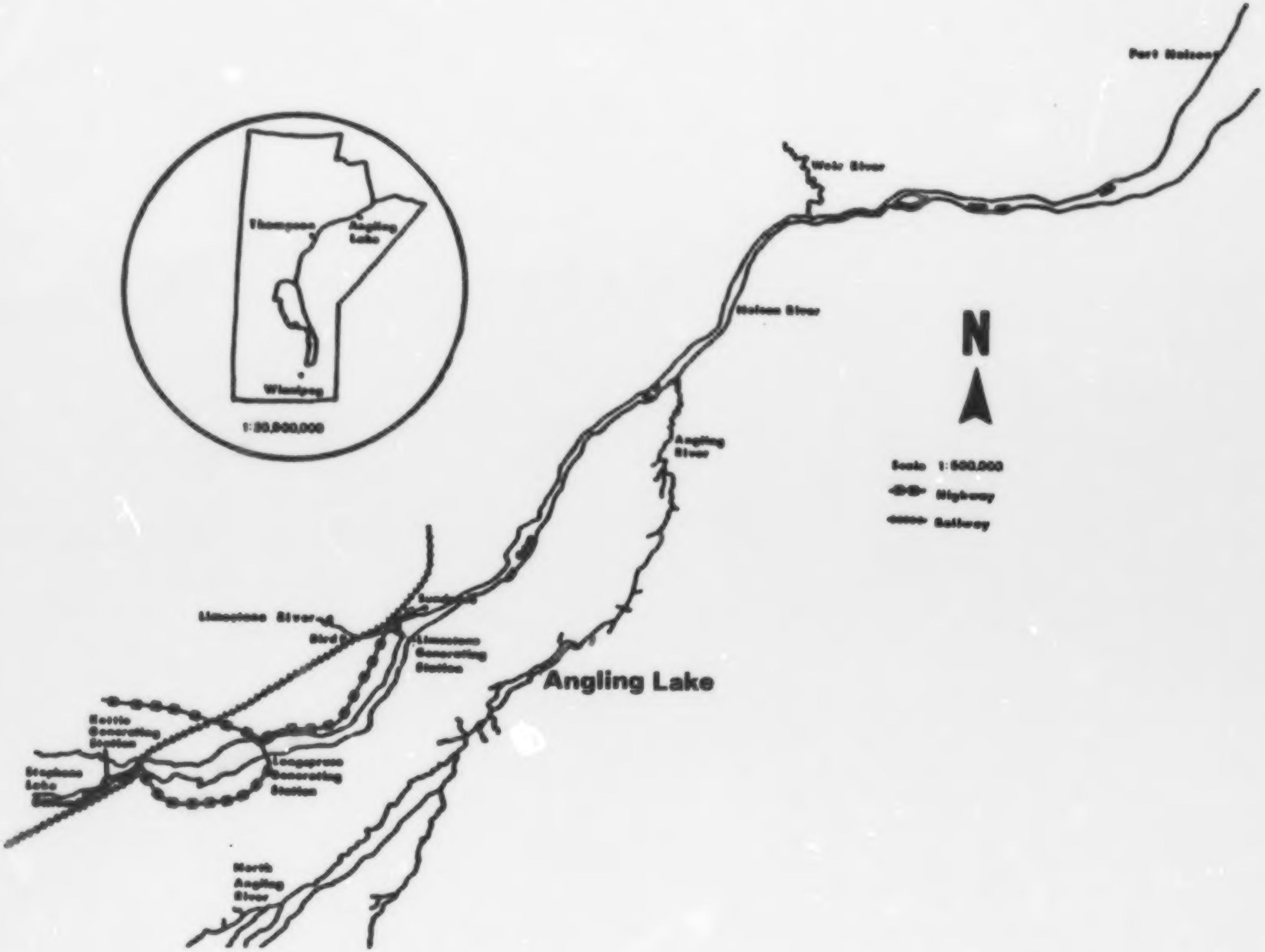

Port Nelson
Weir River
Nelson River
N
Scale 1:500,000
Highway
Railway
Angling River
Angling Lake
Limestone River
Bird
Limestone Generating Station
Kettle Generating Station
Longspruce Generating Station
Stephens Lake
North Angling River
Thompson
Angling Lake
Winnipeg

Figure 1. Geographic location of Angling Lake.

METHODS AND MATERIALS

Angling Lake was netted using various combinations of 25 m long 30.5 cm mesh size (stretch measure) gill nets. Initially, net set locations were chosen according to previous test netting results on Angling Lake (Swanson et al.1988). Once areas where high concentrations of sturgeon were found, these were fished intensively until the quota of radio-transmitter tagging was filled (n=10). Radio transmitters were attached as per Swanson and Kansas (1987) with slight modifications in attachment procedure.

In order to avoid recapturing previously tagged sturgeon, efforts were made to avoid resetting nets where transmitters were already affixed to sturgeon.

All sturgeon captured were sampled for fork and total lengths and weight. Sturgeon deemed too small to be radio tagged were tagged with a numbered disc tag as per Swanson et al. (1988). Pectoral fin spines were removed for age determination as per Wilson (1987) and to assess growth (Sunde 1961). Approximately half (n=4) of the total sample was selected for the above procedure in order to assess the effects, if any, of pectoral fin spine removal on individual sturgeon movement.

Radio transmitters were tracked by helicopter as per Swanson (1986). Flights were made every two weeks depending on aircraft availability, weather and manpower constraints.

Included in this report are radio-tagged sturgeon from 1986 (Swanson and Kansas 1987). Tag frequencies 48.061 Mhz and 48.222 Mhz moved into Angling Lake sometime in the spring of 1987 and have remained there since.

Radio-tracking flights covered in this report are from September 17, 1988 (nine days after tagging) up to and including April 13, 1989. There were 11 individual flights during this period tracked by Fisheries Branch staff and local N.R.O.'s .

RESULTS

A total of 11 sturgeon were captured from August 24-28, 1988. Ten were tagged with radio transmitters and one was tagged with a numbered disc tag. The 10 sturgeon affixed with radio transmitters had an average length and weight of 1148 mm and 9.8 kg respectively. Table 1 presents all pertinent data including individual lengths, weights, transmitter frequency and age.

Most sturgeon (n=10) were captured in the narrows region of Angling lake and one was captured in the south-basin area (Figure 2). Two previously radio-tagged sturgeon were recaptured during the capture/tagging period (August 27-28) with no apparent damage to fish or transmitter by the netting gear. Sturgeon fin-clipped for ageing samples show negligible differences in movement from those not fin-clipped.

Tag frequencies 48.222 Mhz and 48.061 Mhz are reported from May 12, 1988 to April 13, 1989. There were 17 individual flights during this period.

Movements

Tag frequency 49.448 Mhz (Figure 3) showed initial upstream movement within 10 days after tagging, into the deepest basin of Angling Lake (approx. 8-9 m). It remained in this general area throughout this report period with only slight wanderings within the main basin.

Tag frequency 49.468 Mhz (Figure 4) showed similar post-tagging movement but it moved approximately 12 km upstream. The next

Table 1. Tagging information for sturgeon caught in Angling Lake in 1988.

Date tagged	Total length (mm)	Weight (gms)	Age	Frequency (MHz)
27.08.88	1118	8300		49.568
27.08.88	1118	9000		49.589
27.08.88	1009	7000		49.628
27.08.88	1213	10000		49.608
27.08.88	1168	11300		49.528
27.08.88	1118	8100		49.549
28.08.88	1111	7750	42	49.508
28.08.88	1346	17100	59	49.468
28.08.88	1162	10400	45	49.489
28.08.88	1118	9000	37	49.448

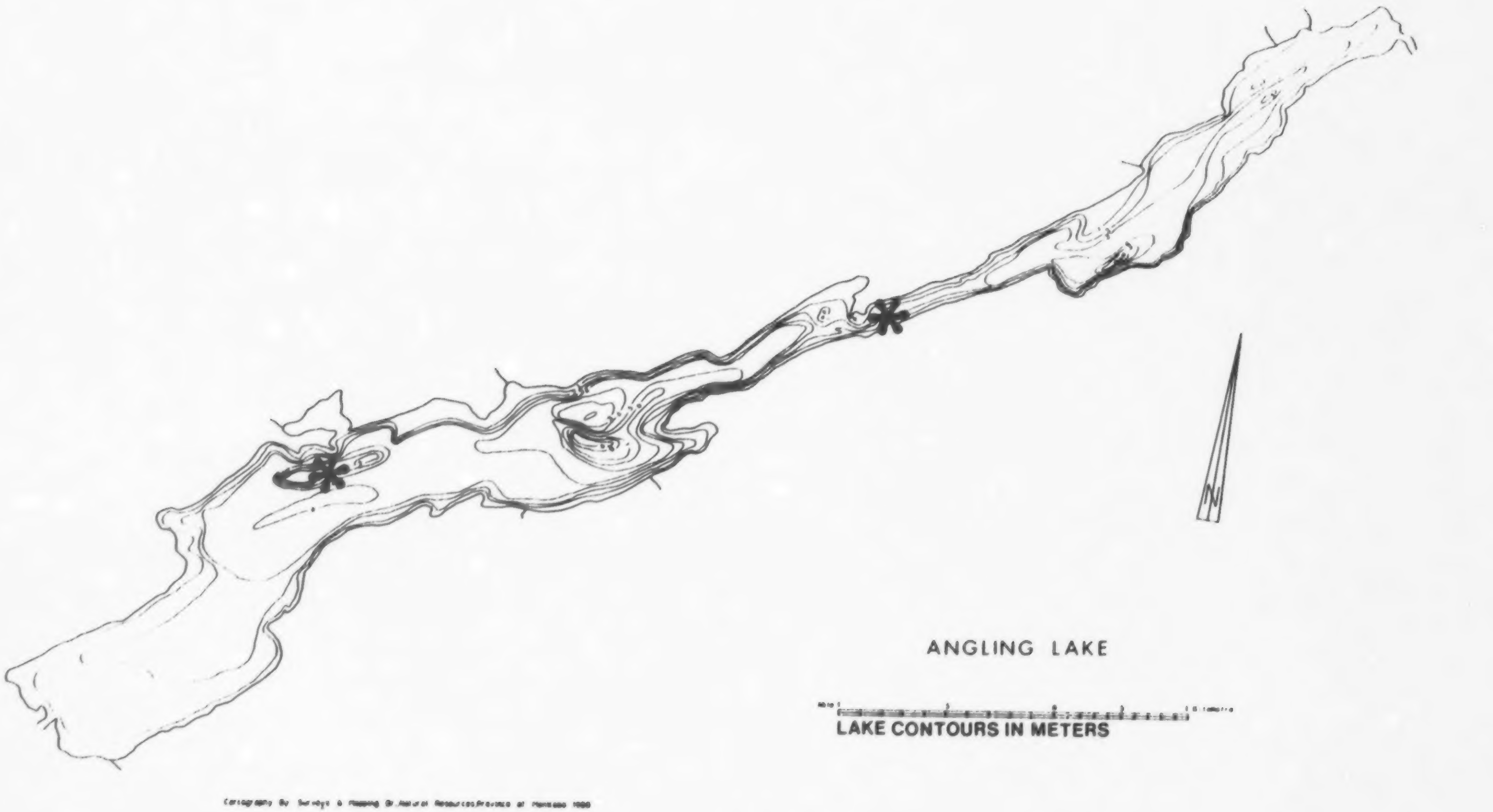

ANGLING LAKE
LAKE CONTOURS IN METERS
N

Fig. 2. Capture locations (*) for sturgeon caught in Angling Lake in 1988.

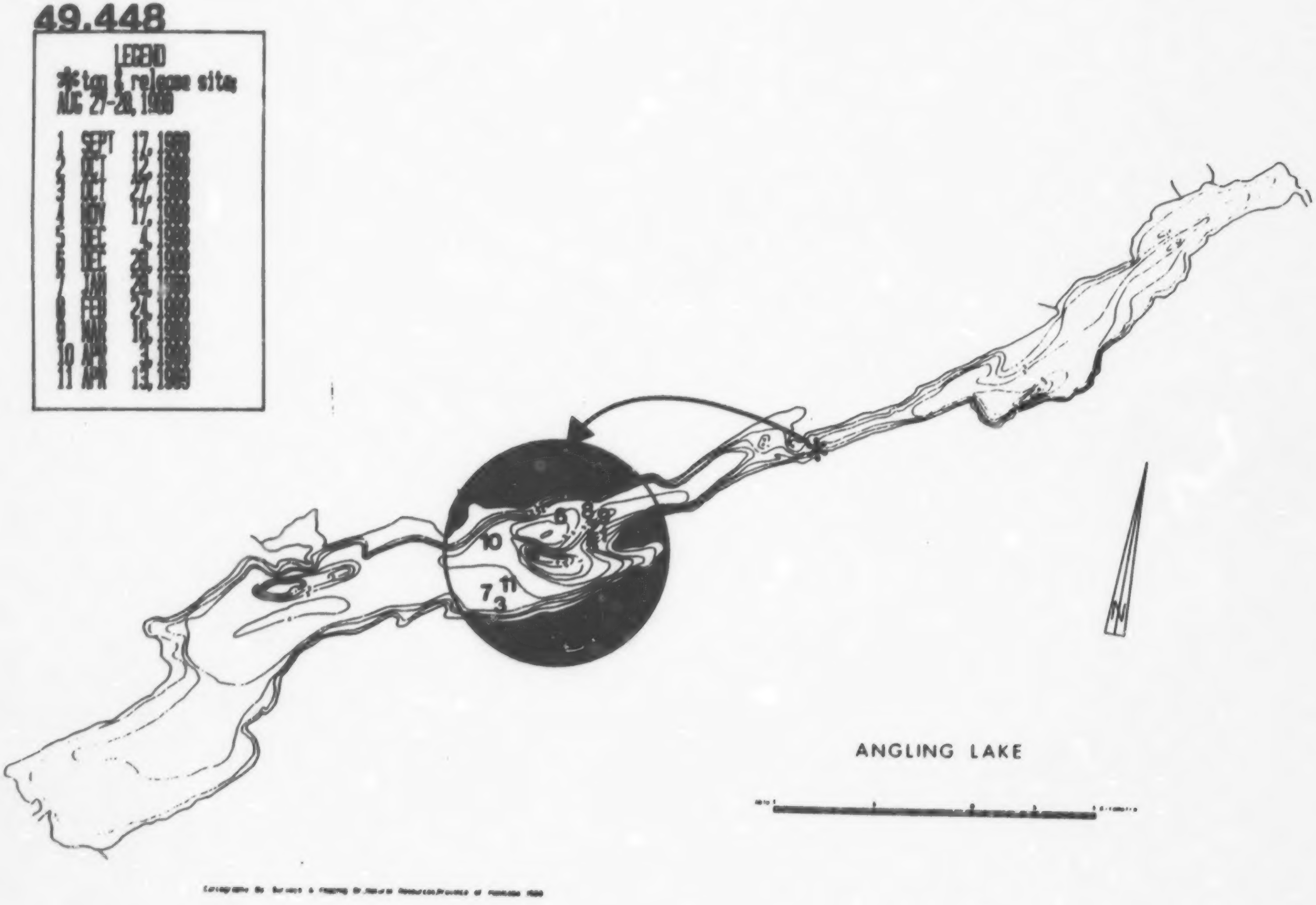

49.448
LEGEND
✱ tag & release site:
AUG 27-28, 1988
1 SEPT 17, 1988
2 OCT 12,
3 OCT 27,
4 NOV 17,
5 DEC 4,
6 DEC 28,
7 JAN 24,
8 FEB 24,
9 MAR 16,
10 APR 3,
11 APR 13, 1989
10
7
11
3
6
8
9
ANGLING LAKE
N

Fig. 3. Movements of radio-tagged sturgeon 49.448 Mhz.

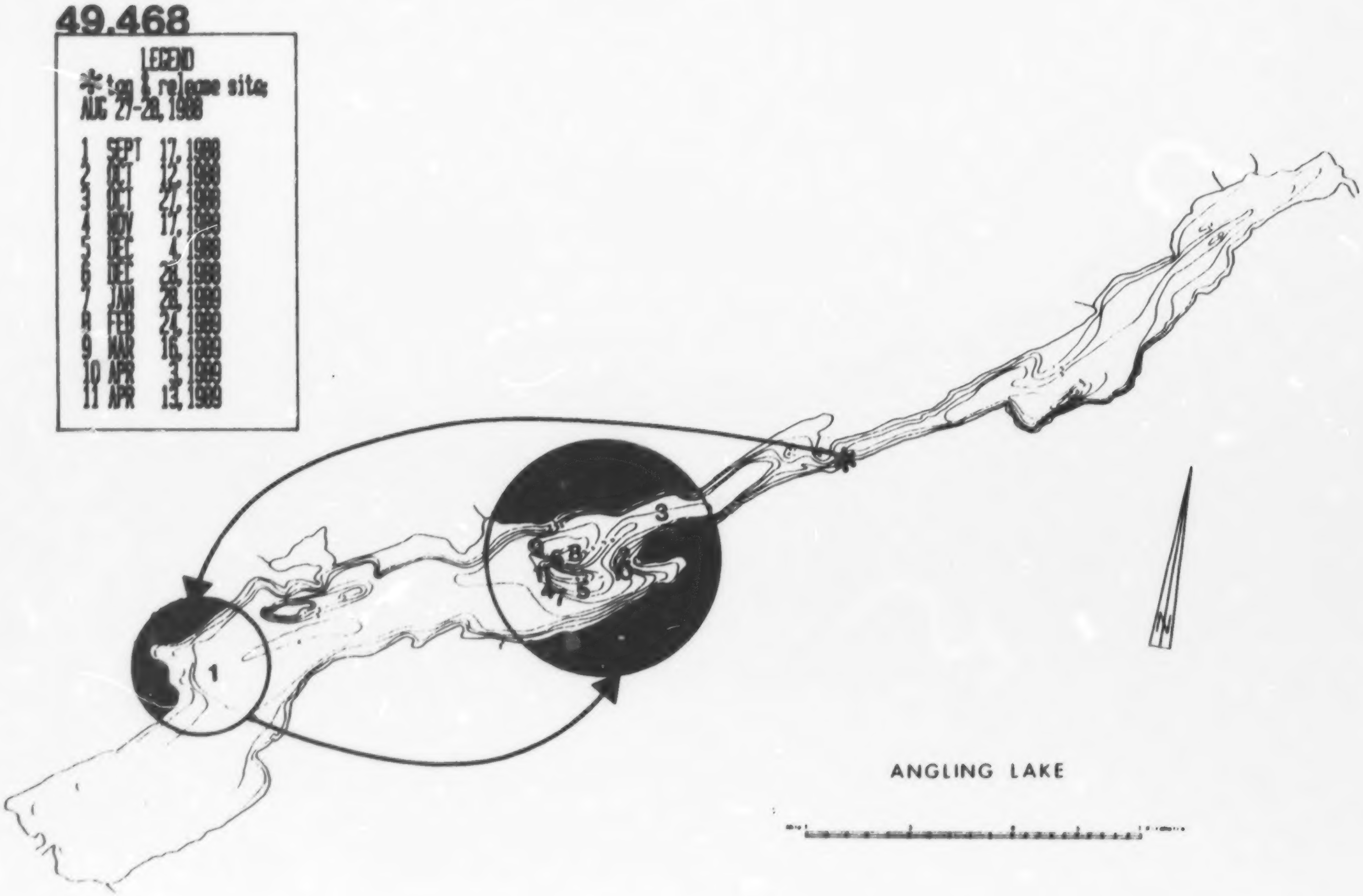

49.468
LEGEND
* tag & release site;
AUG 27-28, 1988
1 SEPT 17, 1988
2 OCT 12, 1988
3 OCT 27, 1988
4 NOV 17, 1988
5 DEC 4, 1988
6 DEC 28, 1988
7 JAN 28, 1989
8 FEB 24, 1989
9 MAR 16, 1989
10 APR 3, 1989
11 APR 13, 1989
1
3
9
8
6
4,7
5
N
ANGLING LAKE

Fig. 4. Movements of radio-tagged sturgeon 49.468 Mhz.

tracking flight revealed this fish had moved to the same area as 49.468 Mhz and it remained there for the duration of the report period.

Tag frequency 49.489 Mhz (Figure 5) moved upstream initially as well (10 km) and remained in a portion of the lake adjacent to that inhabited by the previously noted sturgeon. This area of the lake is shallower by 2-3 m and less mud-bottomed.

Tag frequency 49.508 Mhz (Figure 6) initially moved into the deepest portion of the lake as did 49.448 and 49.468 Mhz. On one occasion it wandered out of this area (October 12, 1988) but returned by the next tracking flight (October 27, 1988).

Tag frequency 49.528 Mhz (Figure 7) moved upstream initially to the deep portion of the lake but by the next tracking flight (3 weeks later) moved further upstream to the same area as previously described for 49.489 Mhz.

Tag frequency 49.628 Mhz (Figure 8) was first tracked 4 km downstream of the release site, but by the next tracking flight (October 12, 1988) was located in the deep portion of Angling Lake. On March 16, 1989 this fish was located in the narrows portion of the lake, however it returned back to the deep portion by the next tracking flight (April 3, 1989).

Tag frequency 49.568 Mhz (Figure 9) was the only sturgeon not captured and released in the narrows. It was captured and released off a small island in the western half of the lake. Out of the 11 reported tracking flights, this fish was located in the deepest portion of the lake nine times. On two occasions, October 12, 1988 and March 16, 1989, it moved approximately 4 km west and east from

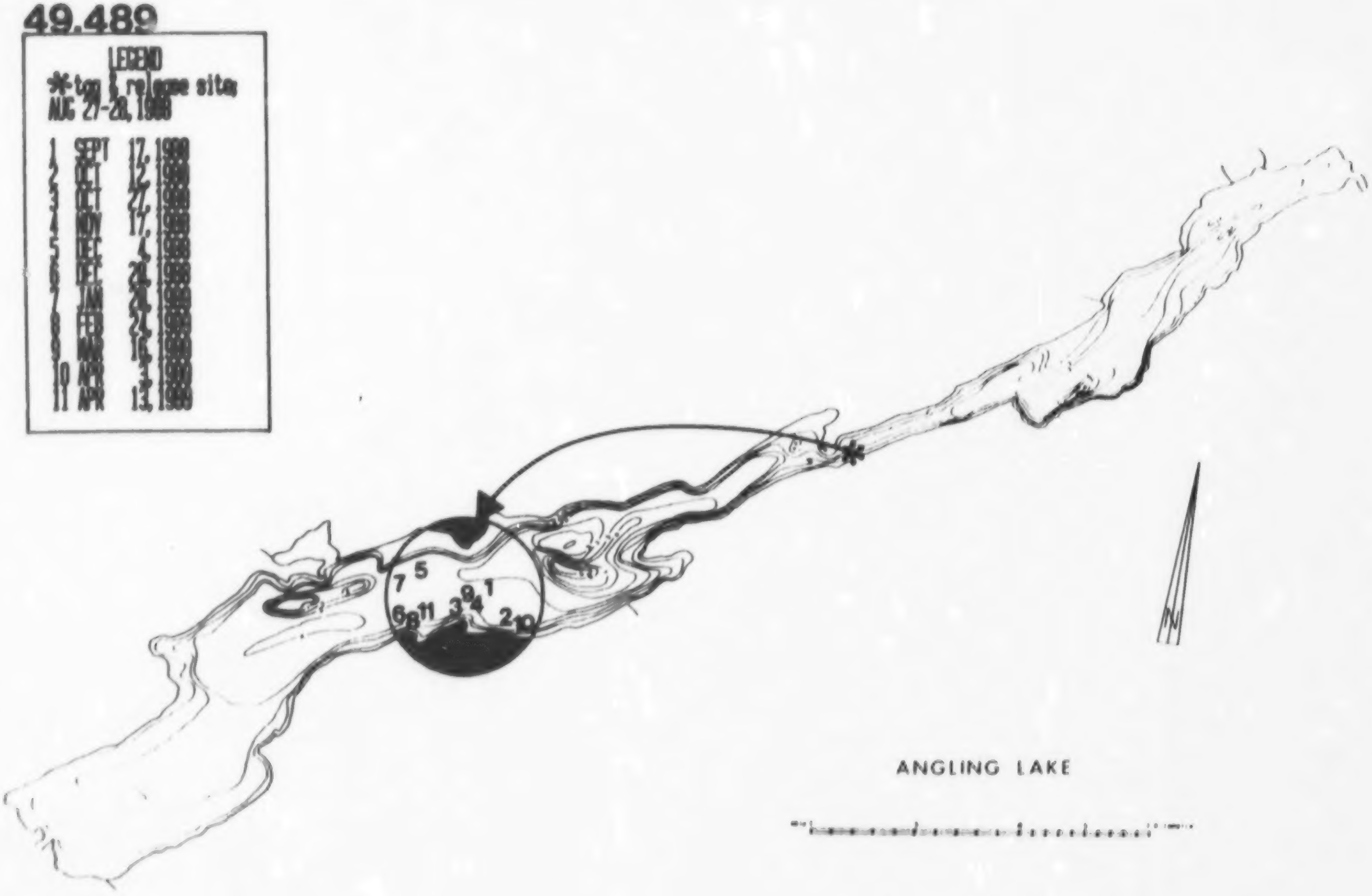

49.489
LEGEND
* tag & release site; AUG 27-28, 1988
1 SEPT 17, 1988
2 OCT 12, 1988
3 OCT 27, 1988
4 NOV 17, 1988
5 DEC 4, 1988
6 DEC 28, 1988
7 JAN 26, 1989
8 FEB 24, 1989
9 MAR 16, 1989
10 APR 3, 1989
11 APR 13, 1989
7 5
9 1
4
6 8 11 3
2 10
N
ANGLING LAKE

Fig. 5. Movements of radio-tagged sturgeon 49.489 Mhz.

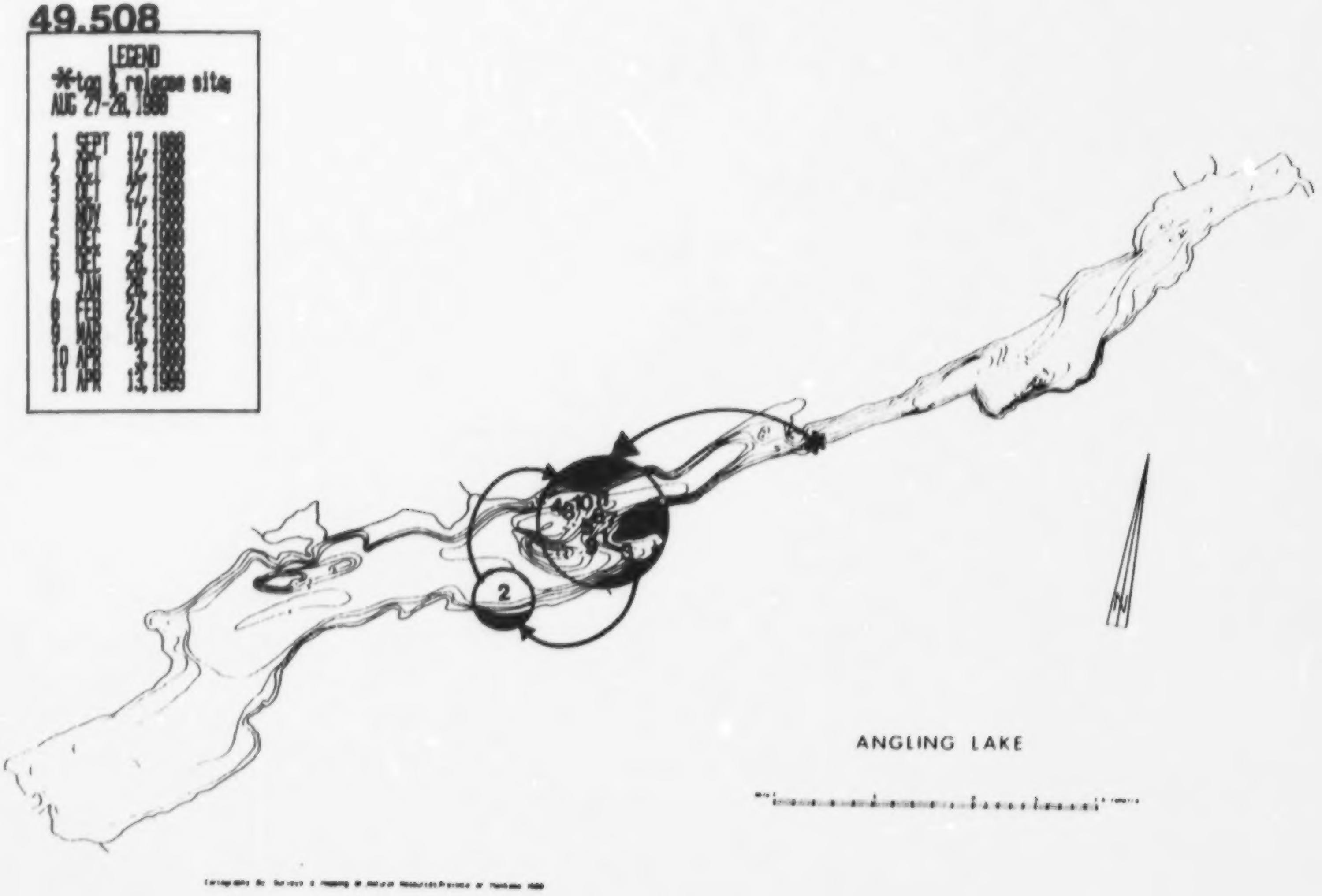

49.508
LEGEND
*tag & release site;
AUG 27-28, 1988
1 SEPT 17, 1988
2 OCT 12, 1988
3 OCT 27, 1988
4 NOV 17, 1988
5 DEC 4, 1988
6 DEC 28, 1988
7 JAN 24, 1989
8 FEB 21, 1989
9 MAR 16, 1989
10 APR 3, 1989
11 APR 13, 1989
2
N
ANGLING LAKE

Fig. 6. Movements of radio-tagged sturgeon 49.508 Mhz.

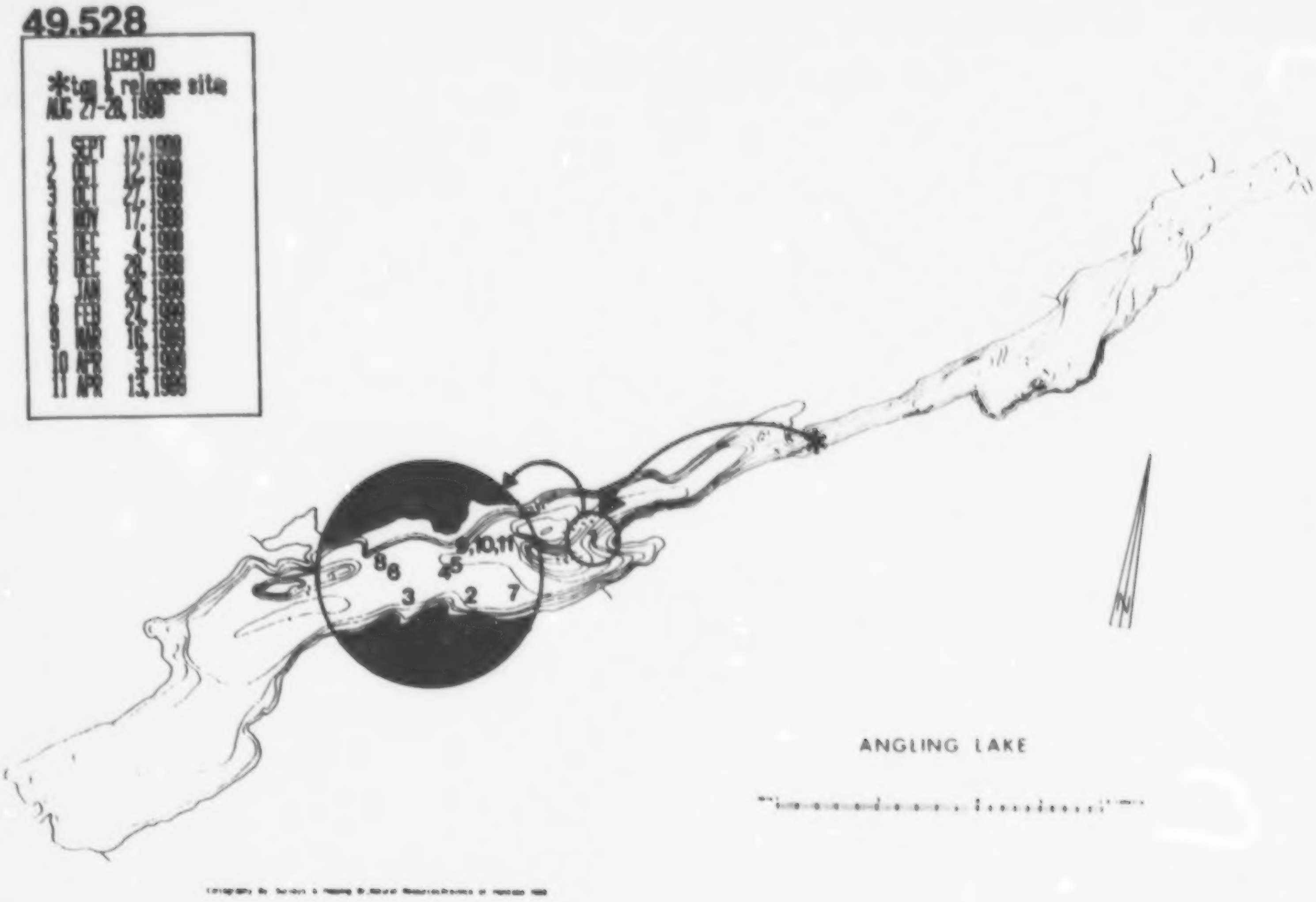

49.528
LEGEND
*tag & release site
AUG 27-28, 1988
1 SEPT 17, 1988
2 OCT 12, 1988
3 OCT 27, 1988
4 NOV 17, 1988
5 DEC 4, 1988
6 DEC 28, 1988
7 JAN 28, 1989
8 FEB 24, 1989
9 MAR 16, 1989
10 APR 3, 1989
11 APR 13, 1989
9,10,11
4 5
8 6
3
2
7
1
ANGLING LAKE

Fig. 7. Movements of radio-tagged sturgeon 49.528 Mhz.

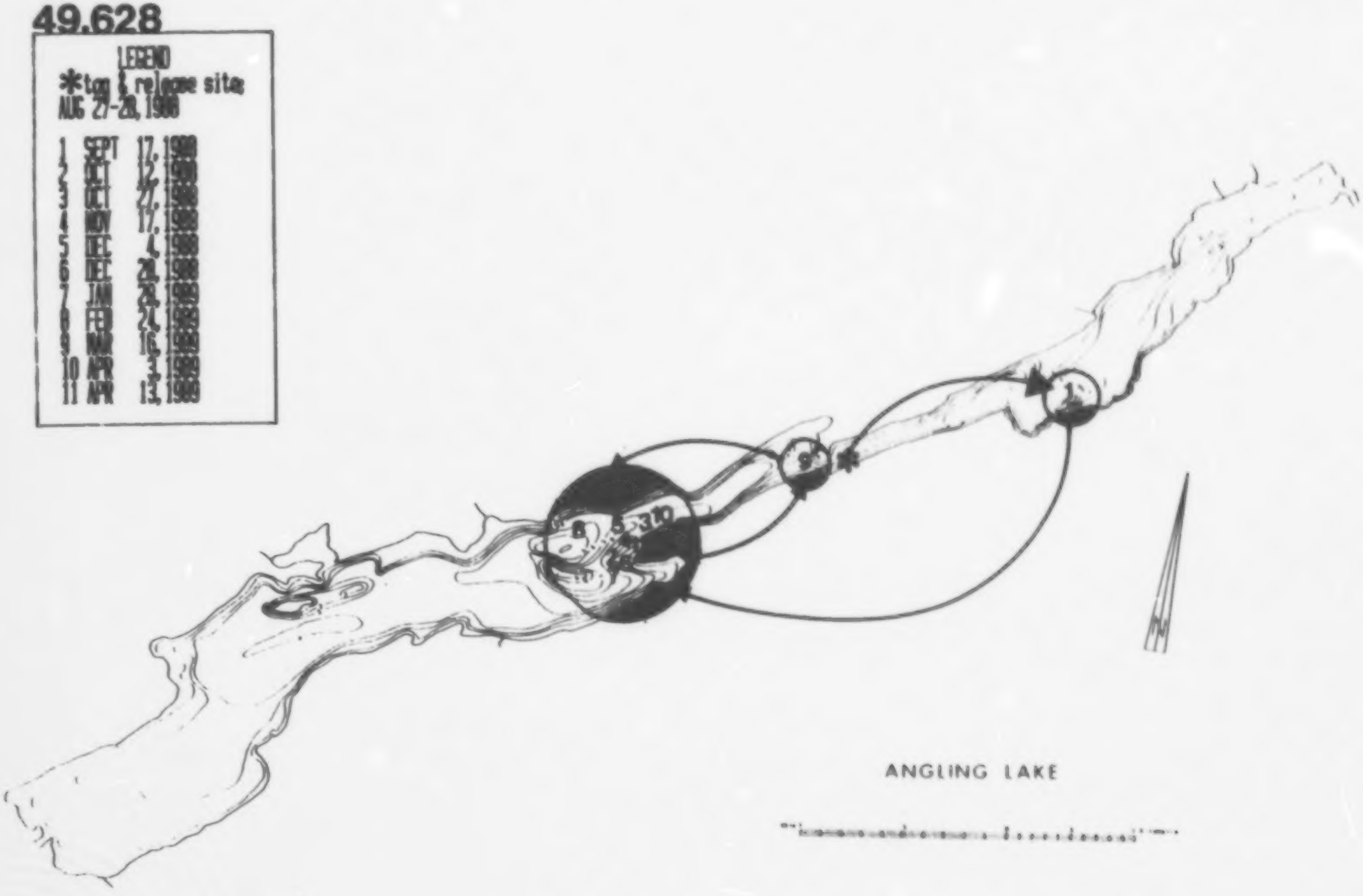

49.628
LEGEND
*tag & release site;
AUG 27-28, 1988
1 SEPT 17, 1988
2 OCT 12, 1988
3 OCT 27, 1988
4 NOV 17, 1988
5 DEC 4, 1988
6 DEC 28, 1988
7 JAN 28, 1989
8 FEB 24, 1989
9 MAR 16, 1989
10 APR 3, 1989
11 APR 13, 1989
ANGLING LAKE

Fig. 8. Movements of radio-tagged sturgeon 49.628 Mhz.

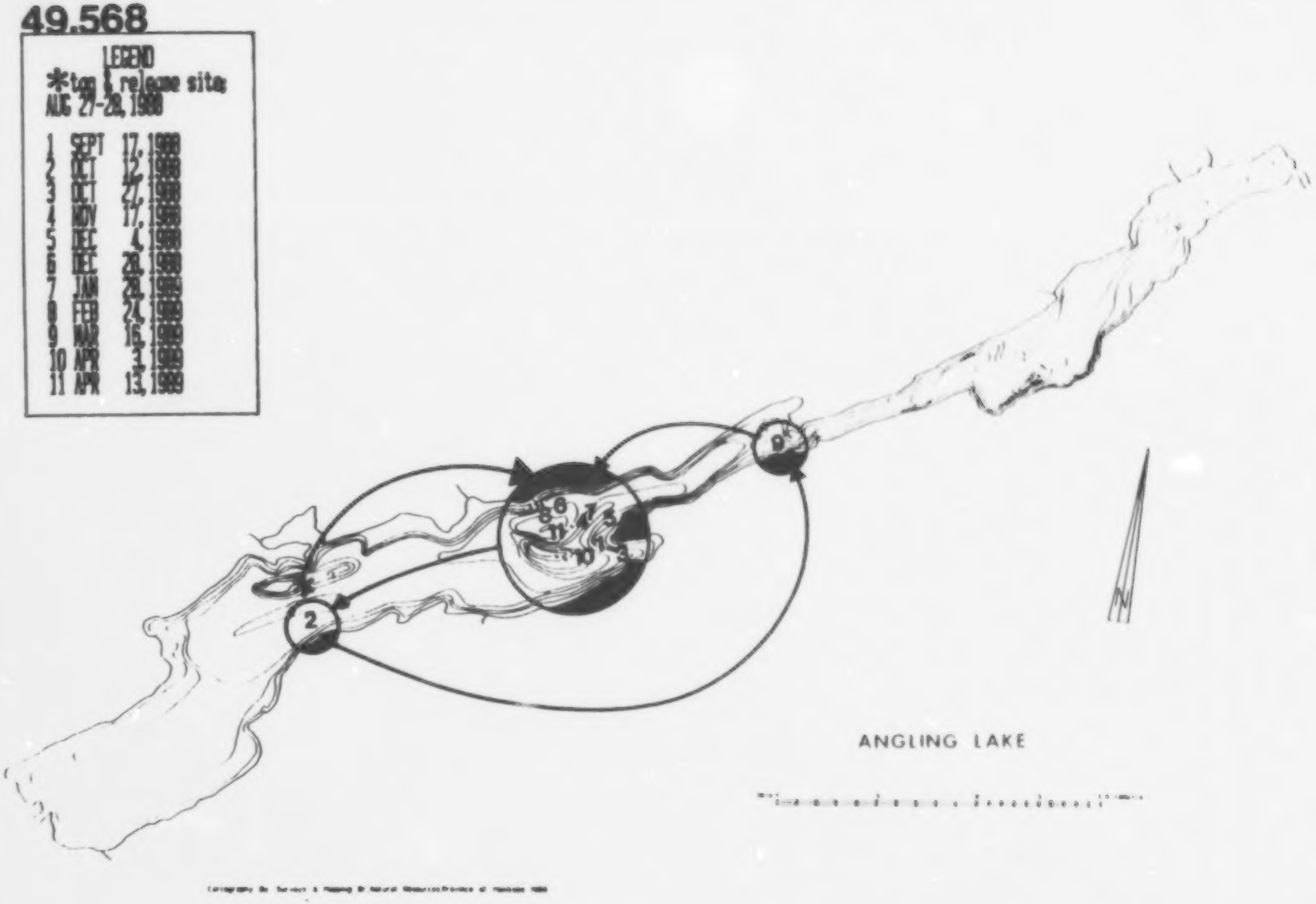

49.568
LEGEND
*tag & release site;
AUG 27-28, 1988
1 SEPT 17, 1988
2 OCT 12, 1988
3 OCT 27, 1988
4 NOV 17, 1988
5 DEC 4, 1988
6 DEC 28, 1988
7 JAN 28, 1989
8 FEB 24, 1989
9 MAR 16, 1989
10 APR 3, 1989
11 APR 13, 1989
2
9
6
8
11
7
4
5
10
1
3
N
ANGLING LAKE

Fig. 9. Movements of radio-tagged sturgeon 49.568 Mhz.

the area respectively.

Tag frequency 49.589 Mhz (Figure 10) was first located 10 km upstream of the release site on September 17, 1988 and remained in this general area until the last tracking flight, April 13, 1989. The depth in this area ranges from 1-3 meters.

Tag frequency 49.549 Mhz (Figure 11) initially moved to, and has remained in, the deepest portion of the lake for all 11 tracking flights.

Tag frequency 49.608 Mhz (Figure 12) also moved to the deepest area of the lake, but on November 17, 1988 was located 3 km from the inflow of the lake. However, by December 28, 1988 this fish was back into the deeper area and has remained there until the last reported tracking date (April 13, 1989).

Tag frequency 48.061 Mhz (Figure 13) was located in the narrows area of Angling Lake on May 12, 1988. Seventeen days later it had made a downstream move to the northeast basin and followed that by an upstream move to the inflow basin approximately two weeks later. On July 4, 1988 this sturgeon was on it's way back to the outflow basin and has remained in this area since August 30, 1988.

Tag frequency 48.222 Mhz (Figure 14) was first located in the outflow basin on May 12, 1988. It has made small movements in this basin since that date up to and including April 13, 1989.

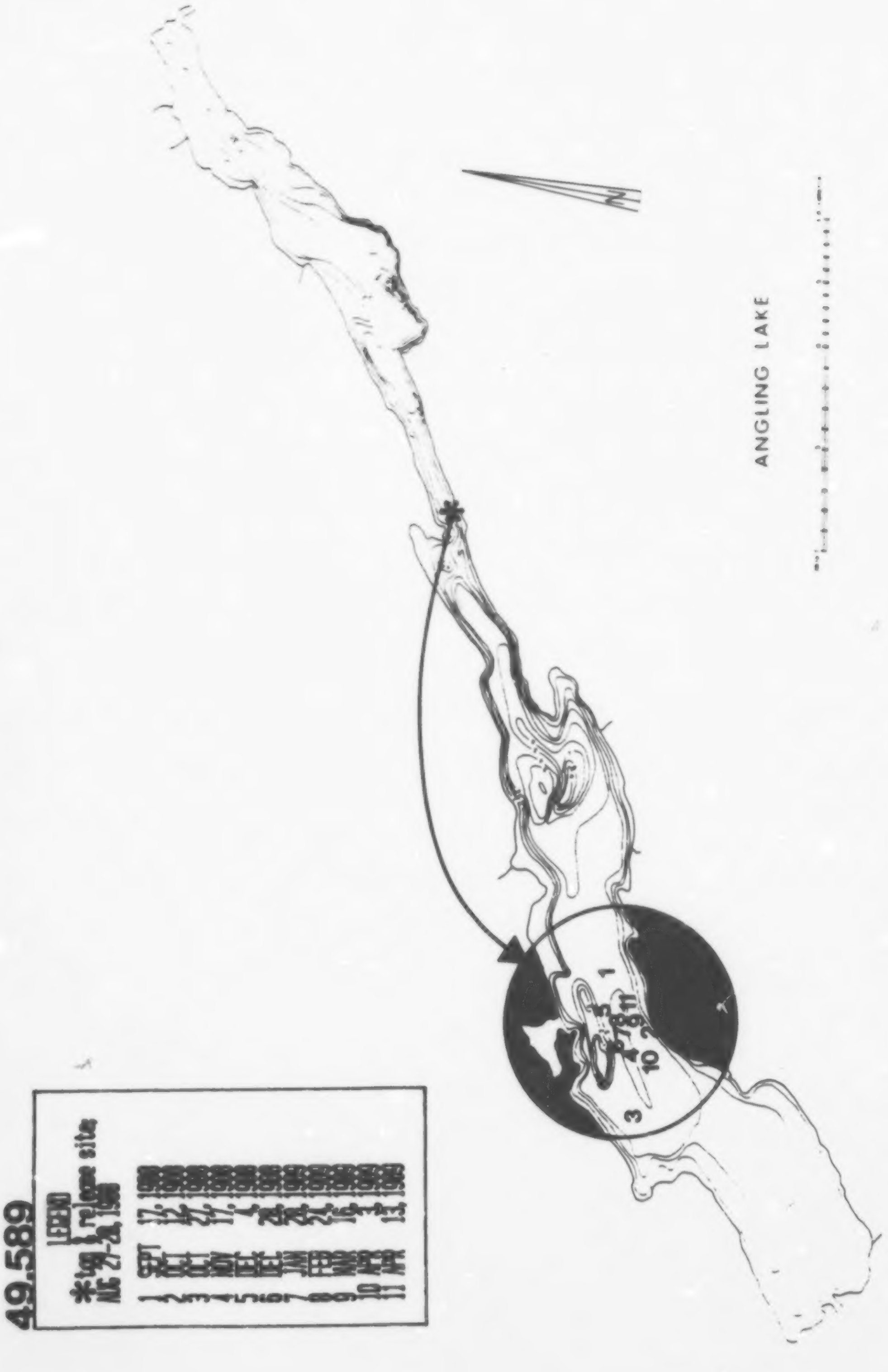
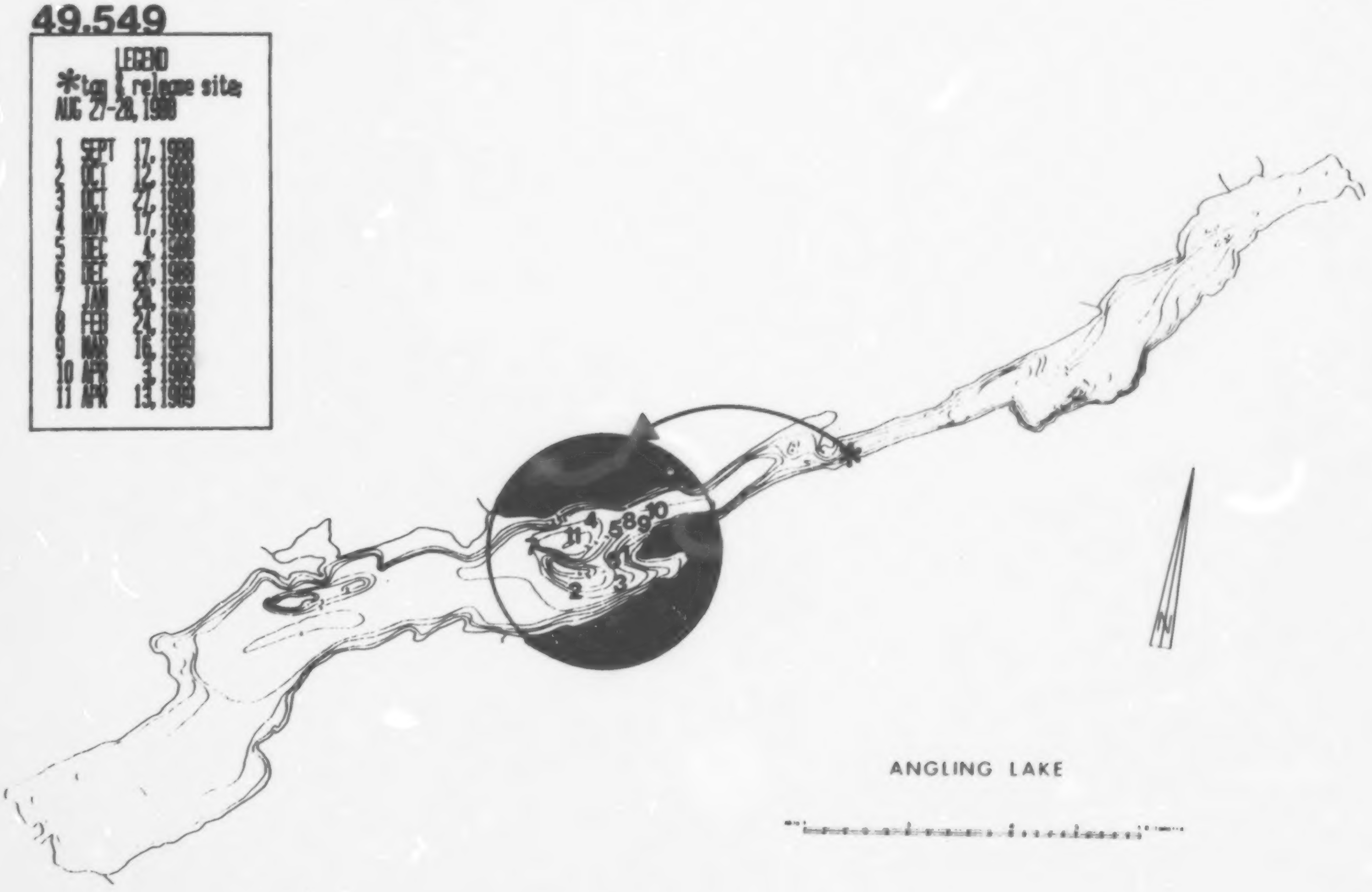

49.589
LEGEND
✳ tag & release site
AUG 27-28, 1988
1 SEPT 17, 1988
2 OCT 12, 1988
3 OCT 27, 1988
4 NOV 17, 1988
5 DEC 4, 1988
6 DEC 28, 1988
7 JAN 26, 1989
8 FEB 21, 1989
9 MAR 16, 1989
10 APR 3, 1989
11 APR 13, 1989
ANGLING LAKE
N
1
3
4
5
7
8
10
11

Fig. 10. Movements of radio-tagged sturgeon 49.589 Mhz.


49.549
LEGEND
*tag & release site;
AUG 27-28, 1988
1 SEPT 17, 1988
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3 OCT 27, 1988
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6 DEC 21, 1988
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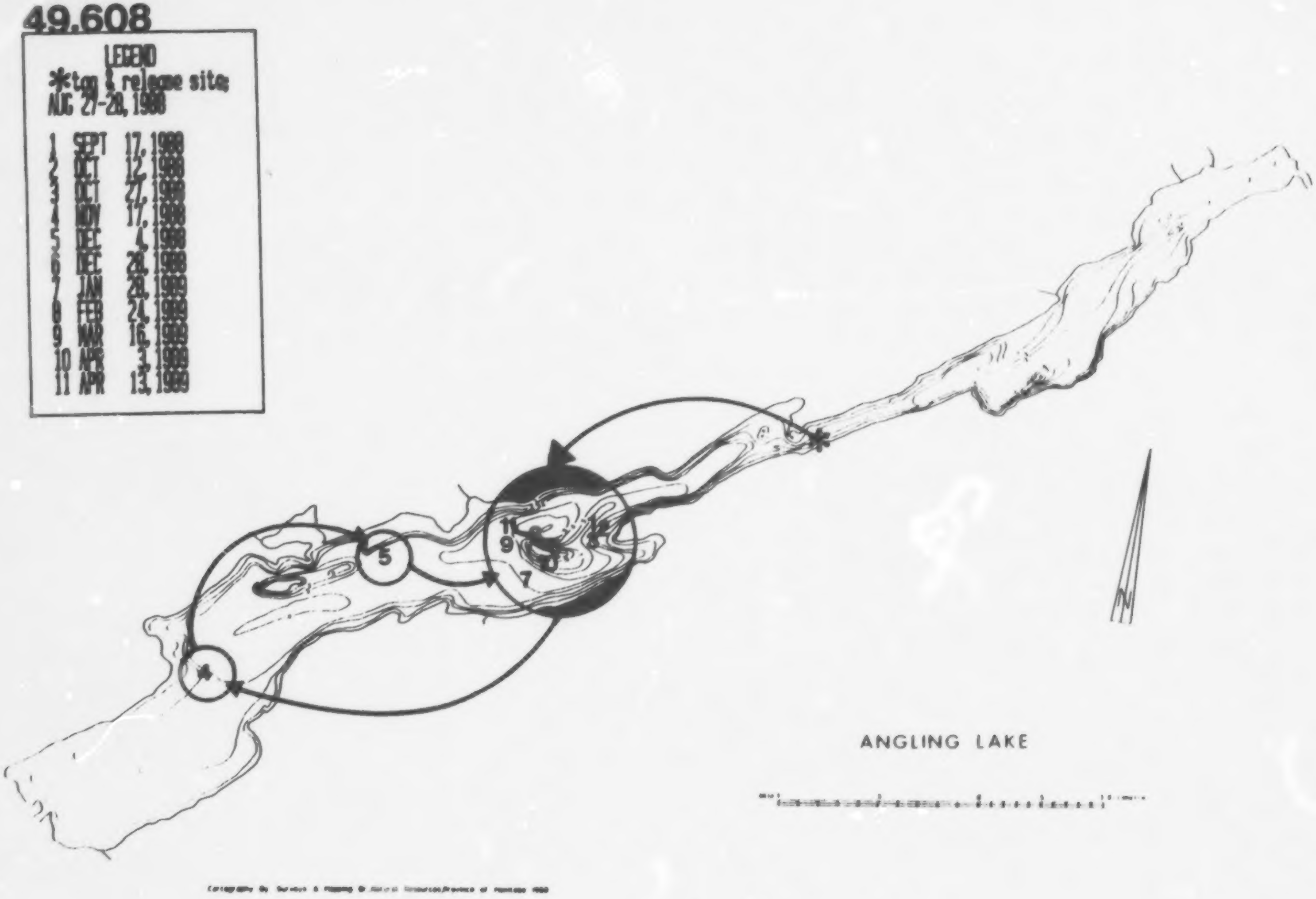
ANGLING LAKE

Fig. 11. Movements of radio-tagged sturgeon 49.549 Mhz.


49.608
LEGEND
*tag & release site;
AUG 27-28, 1988
1 SEPT 17, 1988
2 OCT 12, 1988
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4 NOV 17, 1988
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6 DEC 28, 1988
7 JAN 28, 1989
8 FEB 24, 1989
9 MAR 16, 1989
10 APR 3, 1989
11 APR 13, 1989
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5
4
ANGLING LAKE
N

Fig. 12. Movements of radio-tagged sturgeon 49.608 Mhz.

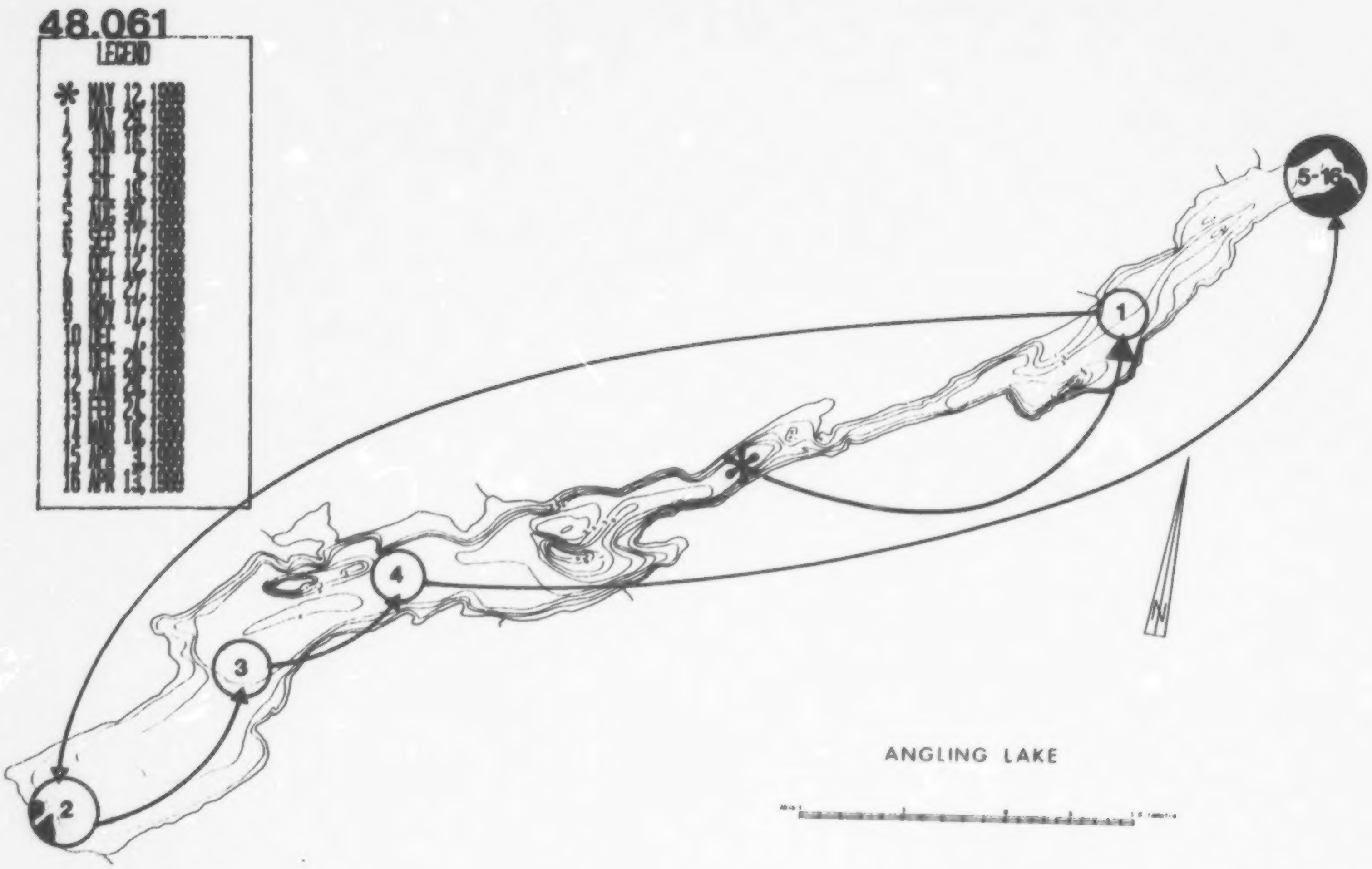
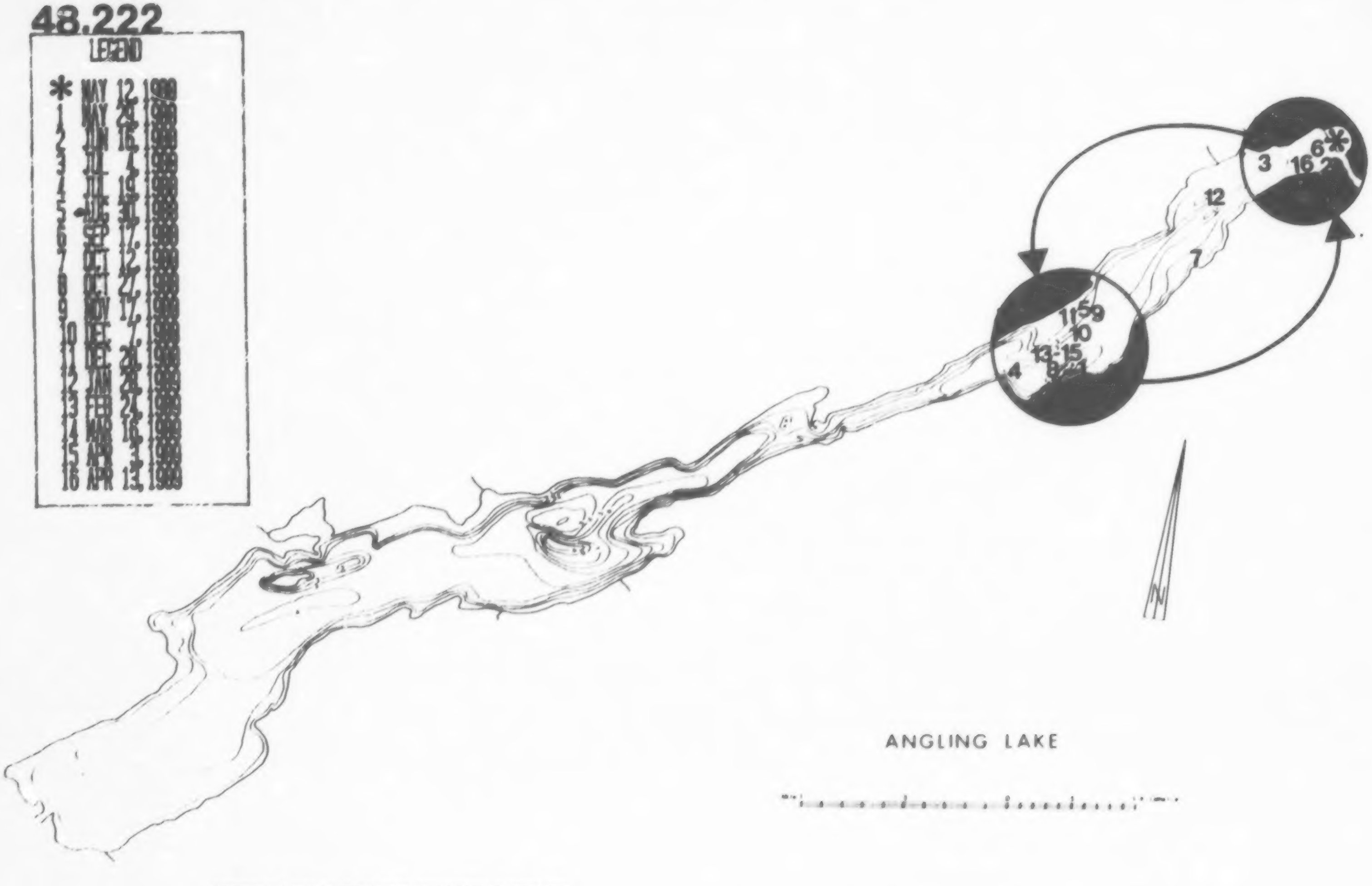

48.061
LEGEND
* MAY 12
1 MAY 24
2 JUN 16
3 JUL 7
4 JUL 19
5 AUG 30
6 SEP 17
7 OCT 12
8 OCT 24
9 NOV 17
10 DEC 7
11 DEC 21
12 JAN 24
13 FEB 27
14 MAR 16
15 APR 3
16 APR 13
1
2
3
4
5-16
*
N
ANGLING LAKE

Fig. 13. Movements of radio-tagged sturgeon 48.061 Mhz.


48.222
LEGEND
* MAY 12 1988
1 MAY 26 1988
2 JUN 16 1988
3 JUL 4 1988
4 JUL 19 1988
5 AUG 30 1988
6 SEP 17 1988
7 OCT 12 1988
8 OCT 27 1988
9 NOV 17 1988
10 DEC 7 1988
11 DEC 20 1988
12 JAN 24 1989
13 FEB 24 1989
14 MAR 16 1989
15 APR 3 1989
16 APR 13 1989
*
3
16
6
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12
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11
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13-15
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4
N
ANGLING LAKE

Fig. 14. Movements of radio-tagged sturgeon 48.222 Mhz.

DISCUSSION

It has been suggested that Angling Lake is a refuge of sorts for Nelson River sturgeon stocks (Swanson et al. 1988). Based on seasonal catch records and radio-telemetry data from previous studies on the lower Nelson River, (Swanson and Kansas 1987; Swanson et al. 1988), Angling Lake fits certain criteria for seasonal and year round habitation by sturgeon (eg. overwintering habitat). Radio tagged sturgeon 48.061 Mhz and 48.222 Mhz which migrated from the Nelson River into Angling Lake in the spring of 1987 now reside there and are in the process of overwintering for the second consecutive year.

Data presented and discussed here are preliminary in nature, therefore any conclusions about the importance of Angling Lake to the lower Nelson River sturgeon stocks will be made in future reports. However, results to date do show some aspects of Angling Lake/River utilization which are worth documenting.

Sturgeon radio tagged in August, 1988 showed sedentary behaviour relative to sturgeon tagged previously in the Nelson River. Angling Lake sturgeon were, however, tagged in late August and this report includes only the period to the following April, theoretically before any major spring movements should occur. Most movement occured immediately following tagging and throughout late summer and early fall. This movement is typical of radio-tagged sturgeon in the lower Nelson River which were monitored in previous studies (Swanson et al. 1988). These movements are believed to be in conjunction with finding a suitable overwintering area such as the estuary of the Nelson River. Sandilands (1987) reports sedentary behaviour during the summer months and movements in the spring and fall. Nowak and Jessop (1987) observed movements by sturgeon in the fall after relatively sedentary behaviour following post-spawning migrations. Since movements of Angling Lake sturgeon tagged in August, 1988 are reported only until the following April, spring and summer movements will not be discussed. However, 48.061 Mhz which was tagged in 1986, exhibited upstream movement in Angling Lake to the inflow of Angling River during the spring of 1988. This spring movement was followed by a subsequent move back to it's summer and winter location in Angling Lake. This could be interpreted as a spawning movement or perhaps it was just a reaction to an ice-free environment and increasing water temperatures.

Sturgeon tagged in Angling Lake all overwintered in the deeper portions of the lake. Tag frequency 48.061 Mhz remained, in large part, at the outflow of Angling Lake where there is open water caused by a year round current. Both these results concur with findings of Swanson et al. (1988), where sturgeon repeatedly overwintered in deeper portions of the Nelson River or an open water area (below the Long Spruce Generating Station).

Since the monitoring of the tagged sturgeon began, each fish seems to show a preference to remain in a certain area of the lake, with only minor moves in and out of their particular area. This shows sedentary behaviour during the winter months as noted in Swanson et al. (1988), but the reasons for utilizing a particular area are unknown.

Sturgeon inhabit Angling Lake probably as a result of spawning migrations and/or opportunistic foraging behaviour. Use as spawning habitat is considered most likely because during the spring Angling River is a more navigable water course than during the rest of the year and represents a potential spawning medium during the sturgeon's spawning period (Swanson et al.1988). If sturgeon use Angling River and/or Lake to spawn in, it is likely that the resultant progeny would also choose this area to reside in. Sturgeon are known to express strong homing tendencies (Priegal and Wirth 1975; Thuemler 1988). It is possible that sturgeon which were hatched in the Angling River system and moved to the Nelson River might return to the area to spawn and subsequently overwinter and feed. However, more complete data are necessary to make any strong conclusions of the above theory. Also, the absence of young of the year sturgeon during an inventory on Angling Lake poses more questions (Swanson et al.1988).

CONCLUSIONS

1. Data collected from existing radio transmitters indicate sturgeon use Angling Lake year round.

2. Previously tagged sturgeon (1986) moved into Angling Lake during the spring freshet. One of these fish exhibited movement within the lake the following spring which could be related to spawning.

3. Sturgeon tagged in Angling Lake showed typical sedentary behaviour during the winter months.

RECOMMENDATIONS

1. Continue to monitor existing radio tags until they expire (2-3 years).

2. Investigate Angling Lake and Angling River for presence or absence of young of the year or juvenile sturgeon during the 1989 field season.

3. Enforcement of the Angling Lake fishery should be intensified in order to minimize the illegal harvest of sturgeon. This can be accomplished year round during the tracking flights.

4. Increase radio telemetry flights in April, May and June of 1989 to identify potential spawning movements and locations.

PART VII

CONAWAPA FOREBAY NETTING

PART VII

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INTRODUCTION

As hydroelectric development progresses on the lower Nelson River (Limestone and Conawapa Generating Stations), the impacts on fisheries resources continue be in need of assessment. Further to studies already done on the lower Nelson River (Swanson and Kansas 1978; Swanson et al.1988) a gill netting program was developed to assess seasonal fish requirements in the stretch of river to be impacted by the creation of a forebay by the proposed Conawapa Generating Station. The netting program was designed to monitor the changes in fish communities over time as the lower Nelson River changes from river to forebay habitat, as well as to predict changes in fish communities over time.

Sturgeon spawning grounds have yet to be identified. Based on sturgeon sightings in the Lower Limestone Rapids (L.L.R.) in June of 1986, the area was chosen as a site to look for evidence of sturgeon spawning in the spring of 1988. The objectives were to identify spawning habitat, flow requirements and evidence of sturgeon recruitment in the lower Nelson River.

METHODS AND MATERIALS

Test Netting Conawapa Forebay

The lower Nelson River was netted from below the Limestone coffer dam to the B-axis of the proposed Conawapa Generating Station (C.G.S.) (Figure 1). Standard river gangs were utilized based on the same design used in Swanson et al. (1988). The gangs consisted of five panels of gillnets 25 m long and 2.5 m deep. Mesh sizes used were 5.1 cm , 7.5 cm , 12.7 cm , 22.9 cm and 30.5 cm stretch measure. The addition of the 5.1 cm panel was the only difference in the 1988 gangs.

Three different habitat types in this portion of the river were netted during three different time periods; spring, summer and fall. This was to assess seasonal fish requirements in this portion of the lower Nelson as well as to try and identify migrations and movements of fish species with the emphasis on sturgeon.

All sturgeon captured were sampled for total length, fork length and weight. Pectoral fin spines were removed for age determination as per Wilson (1987) and to assess growth (Sunde 1961). Sturgeon were live sampled and tagged with a numbered disc tag attached to the caudal fin. Sturgeon were handled with nylon gloves and wounds resulting from fin clipping were treated with isopropyl alcohol to minimize infection.

All other species caught were individually sampled for length and weight. Walleye (Stizostedion vitreum vitreum), sauger (Stizostedion canadense), northern pike (Esox lucius), lake

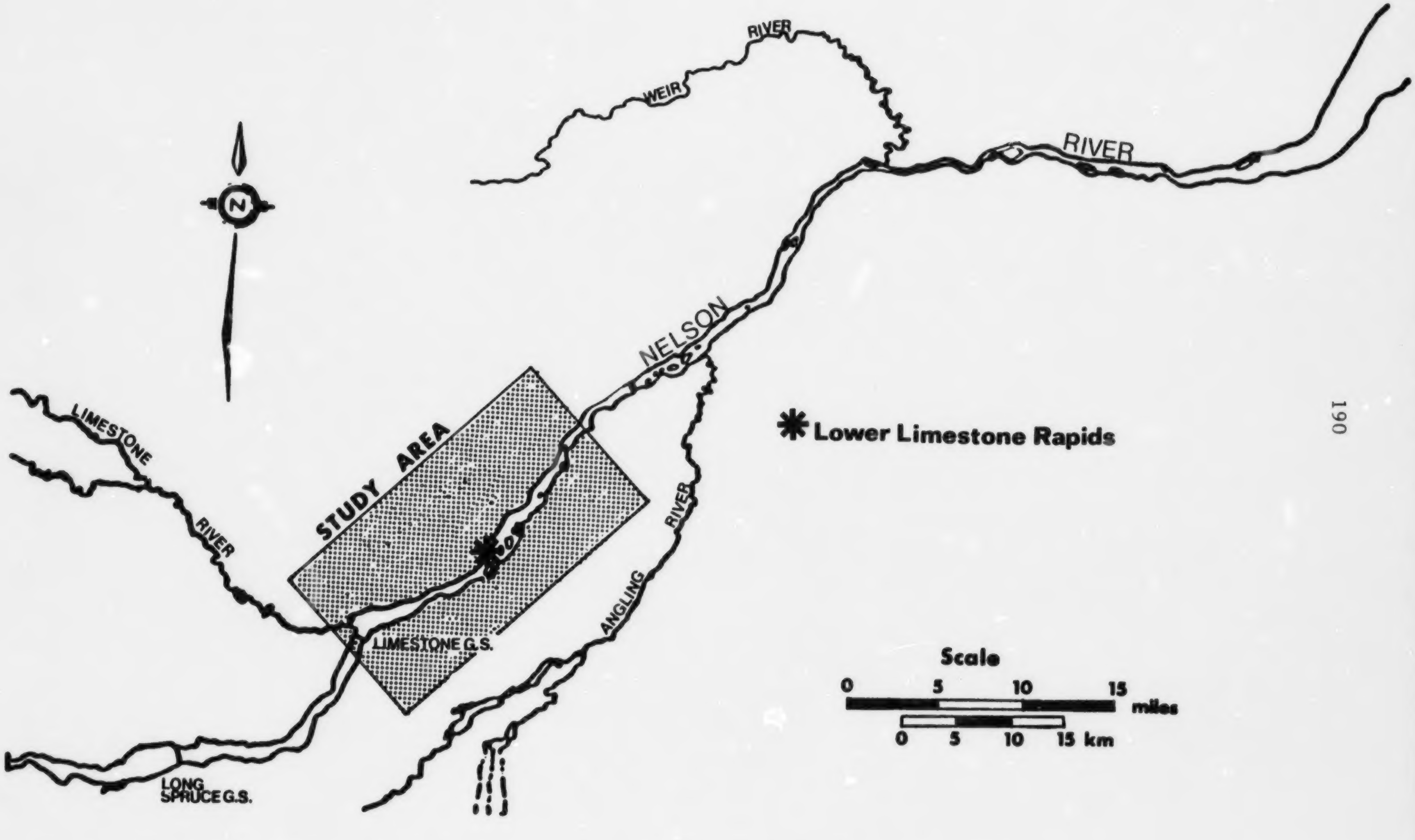
RIVER
WEIR
RIVER
NELSON
Lower Limestone Rapids
STUDY AREA
LIMESTONE
RIVER
LIMESTONE G.S.
ANGLING
RIVER
LONG SPRUCE G.S.
N
Scale
0
5
10
15
miles
0
5
10
15 km

Fig. 1. Study area showing proposed Conawapa forebay and the lower Limestone rapids.

whitefish (Coregonus clupeformis) and goldeye (Hiodon alosoides), were also examined for sex and maturity. For age determination otoliths and dorsal spines were collected from walleyes and saugers, otoliths were collected from whitefish, scales were taken from goldeye and cleithra from northern pike. At or within approximately 500 m of each gillnet site, a 15 m x 1.5 m beach seine was used to sample for forage species and young of the year sturgeon, walleye, northern pike, lake whitefish and goldeye. An attempt was made for this sampling to coincide with the gillnetting program. However, due to the fluctuating water levels associated with upstream hydroelectric generation, this process was hindered.

Lower Limestone Rapids

The Lower Limestone Rapids (L.L.R.) are located approximately 10 km downstream from the Limestone Generating Station (Figure 1). When floating ice in the Nelson River no longer presented a safety concern, a drift bomb sampler was rigged to a 4 m inflatable boat to attempt to collect sturgeon eggs or newly hatched fry in the Lower Limestone Rapids. With previous knowledge of these rapids, and after examining 1:20,000 air-photo maps, two transects were chosen just below the two major shelves of rapids completely traversing the river. Six sampling locations, spaced equally, were then picked along each transect for a five minute "stationary drift" at each site. The drift bomb was securely fastened to an iron T-bar and attached to the inflatable with a hinged apparatus. This allowed the operator to dip the apparatus just below the surface of the water while the driver of the boat used a stop watch to time the event. In an attempt to make a quantitative estimate, a digital flowmeter was secured in the mouth of the drift bomb thus yielding water velocity profiles below the rapids. Stationary drifts were to be taken during both high and low water periods in order to define any difference in fish utilization between the two flow regimes. Water temperatures were taken in the Nelson River immediately following ice break-up and during the sampling period. Documented temperatures for sturgeon spawning activity from existing literature were used (Sopuck 1987; Kempinger 1988; Sunde 1961). In addition, visual observations were recorded by field staff (ie. sturgeon spawning, substrate types).

RESULTS

Test Netting Conawapa Forebay

The lower Nelson River was test netted during the following three periods in 1988: June 23-July 4, August 4-14 and September 19-27. Twenty-eight sturgeon gangs were set yielding 508 fish weighing a total of 367.1 kg and representing ten species. These data are shown in Table 1. Ages are not available, therefore growth analysis is not presented. Three sturgeon were caught during the sampling period and the data are presented in Table 2.

The three habitat types test netted throughout the study were as follows: rapids habitat (nets set as close to the L.L.R. as possible), tributary confluence (at or near the mouths of rivers and creeks) and, Nelson River mainstem (in the river proper, not influenced by rapids or tributaries). Figure 2 shows sampling sites and habitat types for each location. Figure 3 shows catch results for each species by frequency in each habitat in spring , summer and fall. The number of different species for tributary confluence, Nelson River mainstem and rapids habitat were five, seven and ten respectively. Northern pike, white sucker and cisco, respectively, were the most common species in the tributary confluence sets. In Nelson River mainstem sets, longnose sucker, whitefish and white sucker were most common and in rapids habitat sets, longnose sucker, white sucker and cisco were most common. Rapids habitat sets were the only sets to yield sturgeon, sauger and burbot.

Seasonal peaks of each fish species in the different habitat

Table 1. Total catch(frequency), weight(Kg) and catch per unit effort (# or weight/sturgeon gang/24 hours) for all species sampled in the lower Nelson River in 1988.

Species	Freq	CPUE	% Comp	Weight	CPUE	% Comp
Lake whitefish	66	2.36	13.1	39.97	1.43	10.9
Walleye	7	0.25	1.4	4.34	0.16	1.2
Sauger	2	0.07	0.4	0.98	0.04	0.3
Northern pike	70	2.5	13.7	102.47	3.66	27.9
Cisco	40	1.43	7.9	15.39	0.55	4.2
White sucker	49	1.75	9.6	32.06	1.15	8.7
Longnose sucker	251	8.96	49.4	134.22	4.79	36.6
Goldeye	18	0.64	3.5	10.19	0.36	2.8
Lake sturgeon	3	0.11	0.6	26.17	0.93	7.1
Burbot	2	0.07	0.4	1.26	0.05	0.3
Total	508	18.14	100	367.05	13.12	100

Table 2. Tagging data for sturgeon caught in the lower Limestone rapids of the Nelson River in 1988.

Date captured/ released	Mesh size (cm)	Length (mm)	Weight (Kg)	Age	Tag No.
July 2	12.7	550	0.75	11	0093
September 20	30.5	1137	8.63	38	
September 23	30.5	1283	16.8	57	

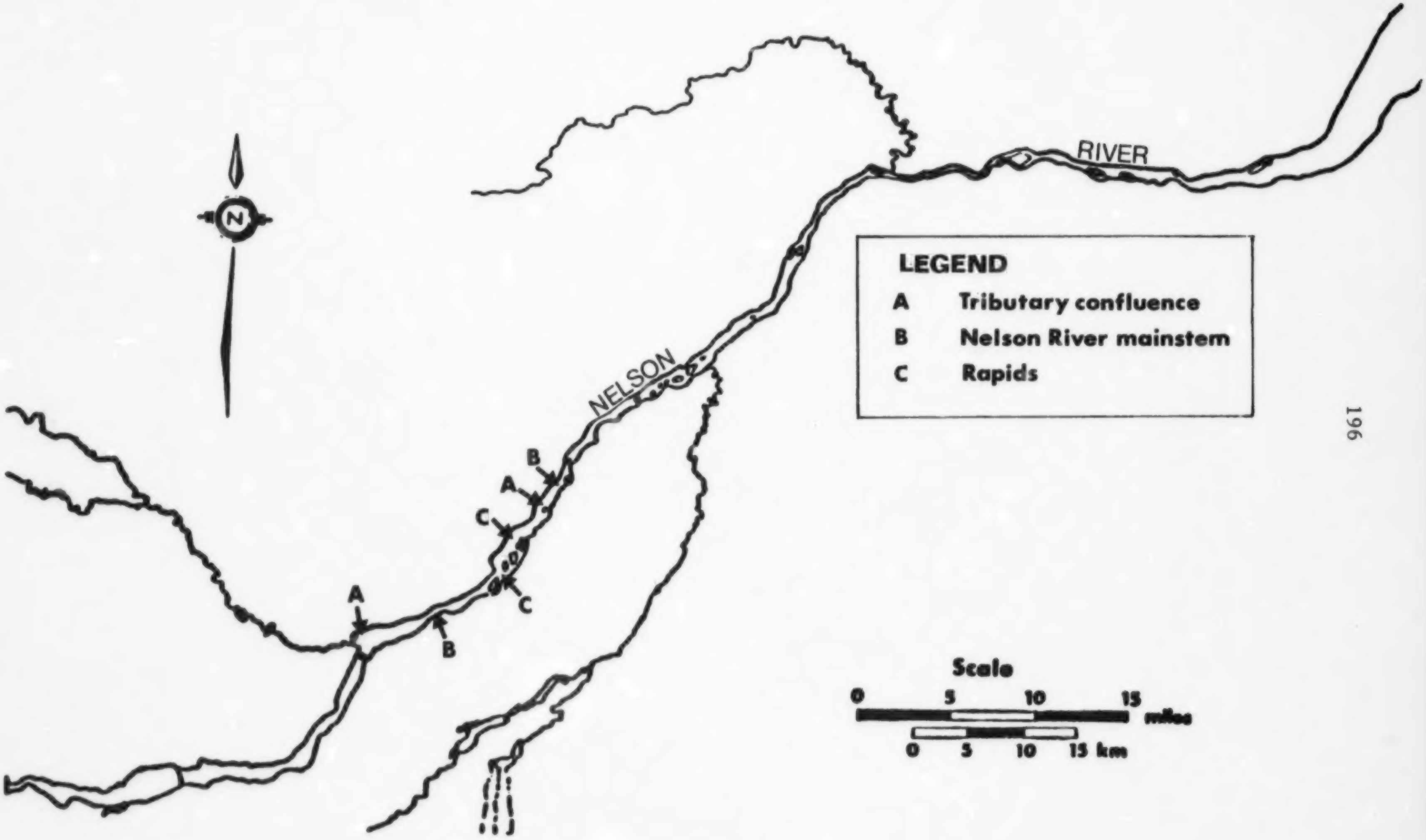
N
RIVER
NELSON
A
B
C
LEGEND
A Tributary confluence
B Nelson River mainstem
C Rapids
Scale
0
5
10
15
miles
0
5
10
15 km

Fig. 2. Net set locations and habitat types for standard river gangs set in the lower Nelson River in 1988.

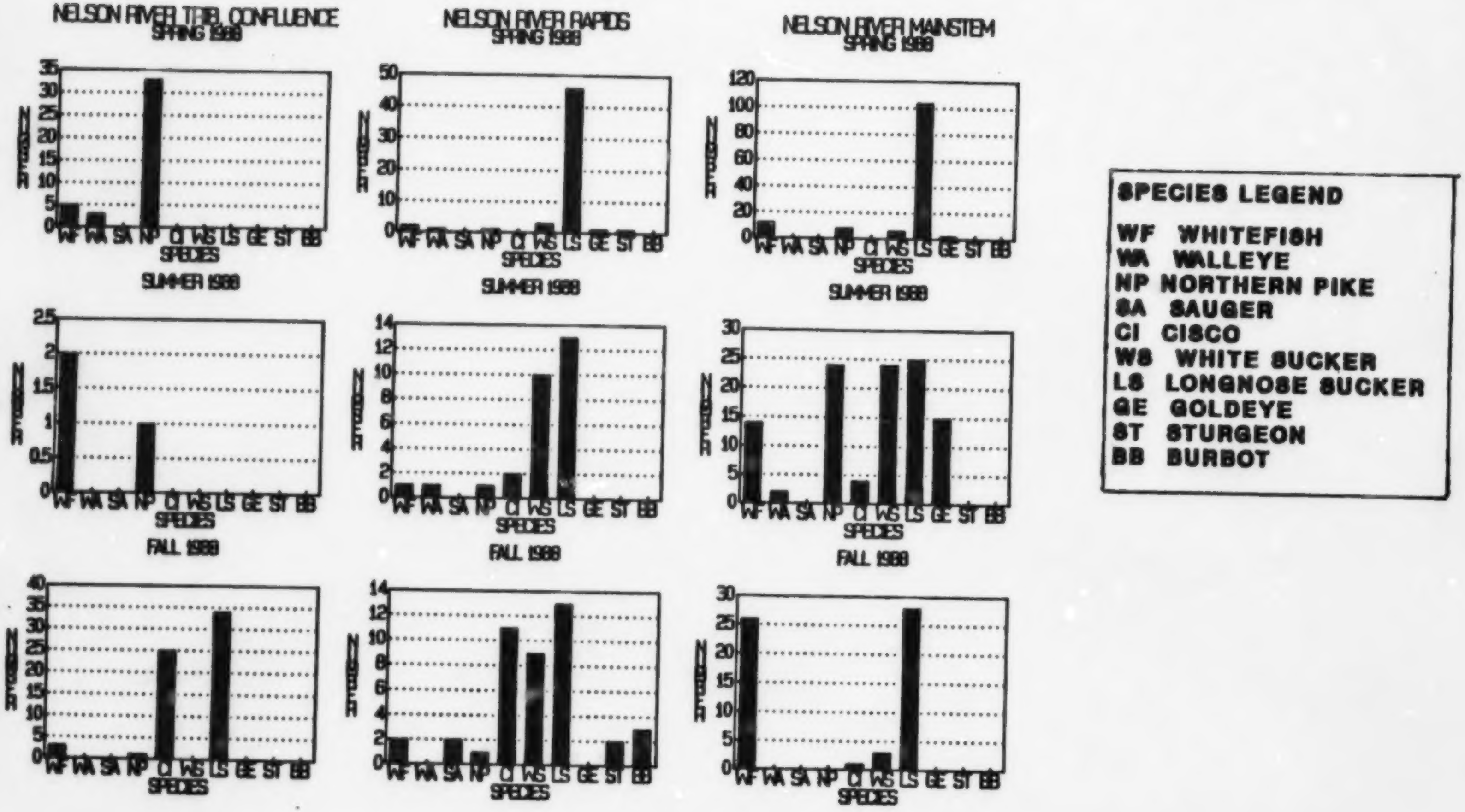

Fig. 3. Seasonal peaks (frequency) of species caught in the lower Nelson River in three different habitat areas.

types are also shown in Figure 3. Sturgeon appeared in the rapids habitat in the spring and fall only. Northern pike were nearly absent in the rapids habitat, peaked in the spring at the tributary confluence and in the summer in the Nelson River mainstem. Whitefish were most numerous at the tributary confluence in summer and in the Nelson River mainstem in fall. Cisco numbers were highest at the tributary confluence in the fall and also in the rapids habitat in the fall. Longnose suckers were prevalent in all areas and seasons except for the tributary confluence in the spring and summer.

Lower Nelson River species composition from test sets in 1988 are compared to species composition from Long Spruce Reservoir (1985/86 combined), in Figure 4. Long Spruce reservoir yielded 12 species to the lower Nelson River's 10. Sturgeon were not found in Long Spruce standard gangs and lake chub, mooneye and freshwater drum were not captured in lower Nelson River gill nets. Whitefish, northern pike, white sucker, cisco and burbot show similar percent composition in both Long Spruce and the lower Nelson River. Long Spruce shows a higher percentage of walleye and sauger while the lower Nelson River sets yielded higher percentages of longnose sucker and goldeye. Longnose sucker was the most prolific species in both cases.

During seining, field staff were unable to adhere to the schedule due to the rapidly varying flow regime. Table 3 presents the total number of each species captured during seining, along with the habitat type they were captured in. Six true forage species are represented; slimy sculpin, johnny darter, trout perch,

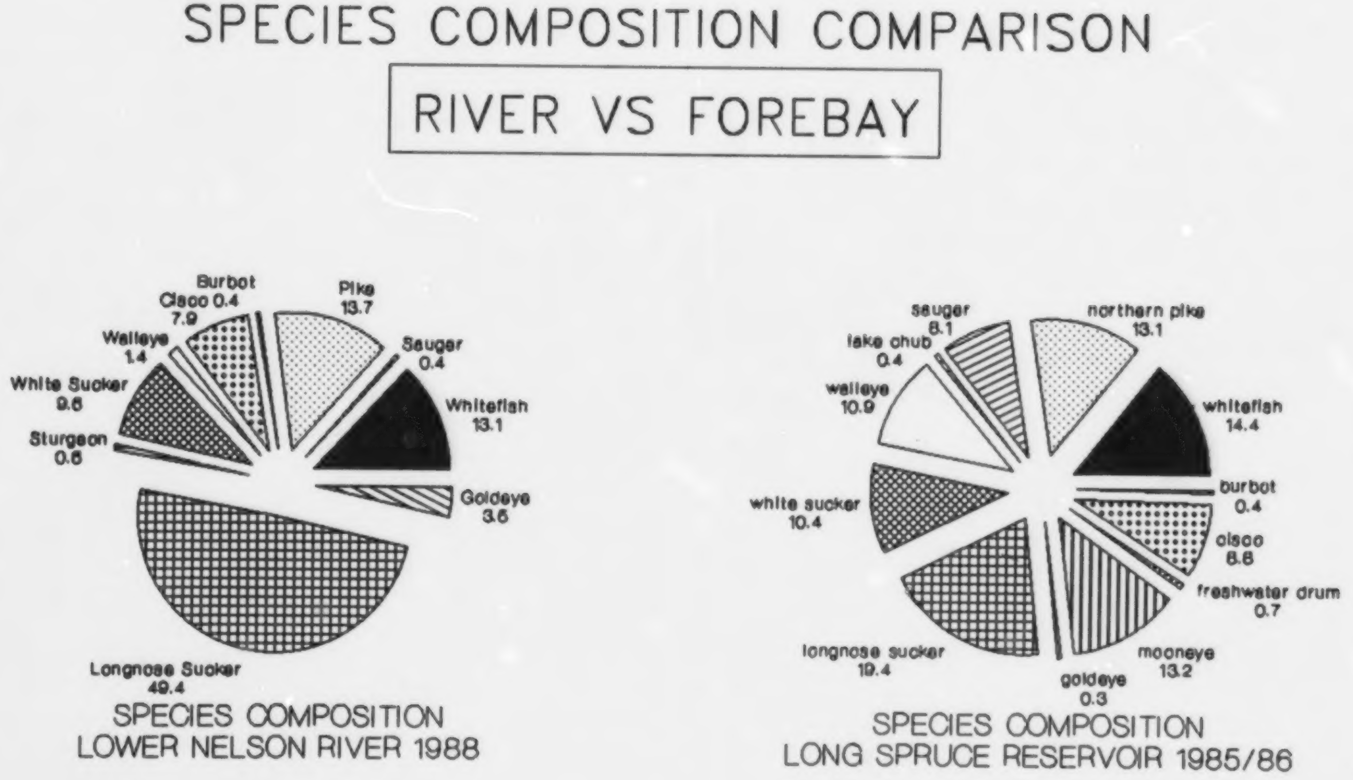

Fig. 4. Species composition comparisons (frequency) between netting conducted in the Long Spruce Reservoir in 1985-86 and the lower Nelson River in 1988.

Table 3. Seine haul results (total number) and habitat(s) which fish species were captured in. (A = tributary confluence, B = rapids habitat, C = Nelson River mainstem).

Species	Total No.	Habitat type
Slimy sculpin (Cottus cognatus)	25	A
Johnny darter (Etheostoma nigrum)	4	A
Trout perch (Percopsis omiscomaycus)	66	B,C
Lake chub (Couesius plumbeus)	1	B
Emerald shiner (Notropis atherinoides)	˜6500	A,B,C
Spottail shiner (Notropis hudsonius)	351	B,C
Lake whitefish (Coregonus clupeaformis)*	4	B
Yellow perch (Perca flavescens)*	290	B
Walleye (Stizostedion vitreum vitreum)*	2	B
White sucker (Catostomus commersoni)*	550	A,B,C
Longnose sucker (Catostomus catostomus)*	˜250	B
Northern pike (Esox lucius)*	5	A
Mooneye (Hiodon tergisus)*	1	B

* denotes young of the year

lake chub, emerald shiner and spottail shiner. Emerald shiner was the most prolific forage species with the greatest frequency, and occurred in all three habitat types. Seven non-forage species were represented in the seine hauls as young of the year fish only. The rapids habitat yielded the greatest number of species, followed by tributary confluence and the Nelson River mainstem.

Lower Limestone Rapids

Stationary drift sampling was performed in the L.L.R. on June 6-7, 1988 when water temperatures ranged from 6°C - 7°C. Sampling was again done on June 16-22, 1988 when the water temperatures ranged from 11°C - 14°C. No sturgeon eggs or fry were captured during either of these sampling periods. Previously planned transects with equal spacing between sites were impossible to sample. The main channel of rapids at peak flow was too dangerous to navigate, let alone complete a stationary drift. As well, low flows prevented navigation by boat due to dewatering of rapids habitat. However, 15 stations were sampled on every day during the sampling period (Figure 5). Thirty additional stationary drifts were done opportunistically throughout the course of the sampling period.

Adult sturgeon were sighted on June 22, 1988 in the L.L.R. at 4:00 - 4:45 p.m. (Figure 5). Approximately 30 sturgeon, .75 m - 1.0 m long, were observed rolling and breaking the surface of the water, apparently going through the spawning ritual. Velocities were taken at the area of the sightings and ranged from .39 m/s - .56 m/s. Most of the sightings occurred behind a large

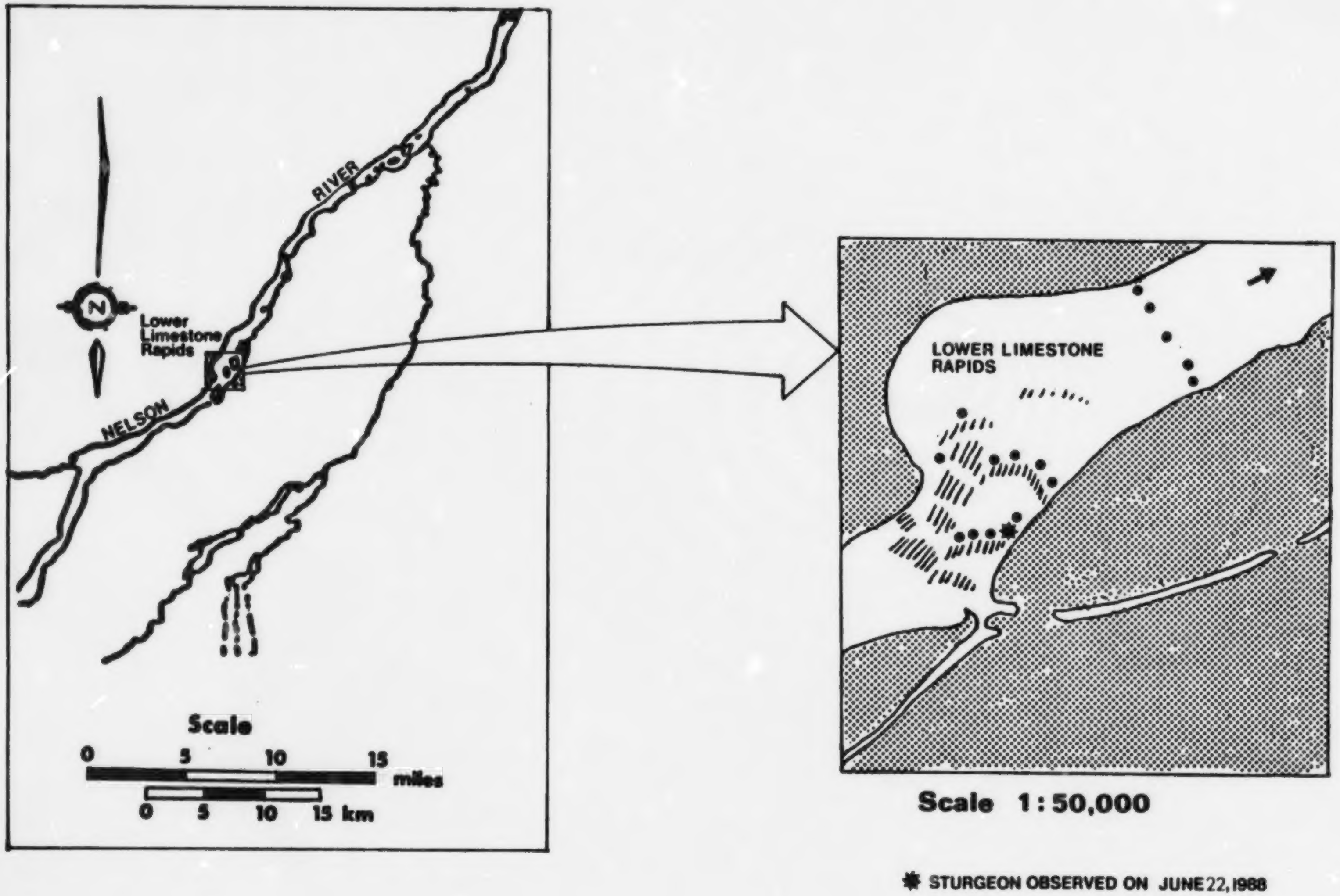
N
Lower
Limestone
Rapids
RIVER
NELSON
Scale
0
5
10
15
miles
0
5
10
15 km
LOWER LIMESTONE
RAPIDS
Scale 1:50,000
✱ STURGEON OBSERVED ON JUNE 22, 1988

Fig. 5. Expanded view of the lower Limestone Rapids study site showing sampling stations (●) and sturgeon spawning observations.

gravel/cobble bar, which was examined the next day on foot at low flow conditions (June 19, 1988). The area was completely dewatered during ponding upstream at the Long Spruce Generating Station (L.S.G.S.), which was necessitated by drought conditions. No sturgeon eggs were found in the area, but a flock of 75 -100 gulls had occupied the immediate area for 1-2 hours and appeared to be feeding. It is possible that they were feeding on eggs since no other food source was evident in the gravel and cobble. However, there is no physical evidence that the gulls were eating sturgeon eggs.

As a result of observing sturgeon activity (possibly spawning) in rapids habitat and later seeing the area dewatered, all subsequent dewatered periods were recorded when observed. These periods of watered and dewatered rapids habitat were compared to L.S.G.S. daily discharge records, with consideration for the four-hour delay for water dishcarged at L.S.G.S. to reach the L.L.R. This analysis was used to estimate that a minimum of 45,000 c.f.s. is required to completely water the L.L.R. habitat. This information along with daily flow records may be used to calculate the number of hours/day that up to 50% of the L.L.R. habitat is dewatered. This was calculated for June 7-30, 1988, a low water year, and June 7-30, 1986, a high water year. Figure 6 shows 1988 average daily discharges from the L.S.G.S. and the number of hours/day of dewatered rapids habitat, or the number of times the hourly average flow was below 45,000 c.f.s.. Figure 7 shows the same for 1986. In 1986 there was no dewatering of rapids habitat at the L.L.R. for the reported period. Conversely, in 1988 at

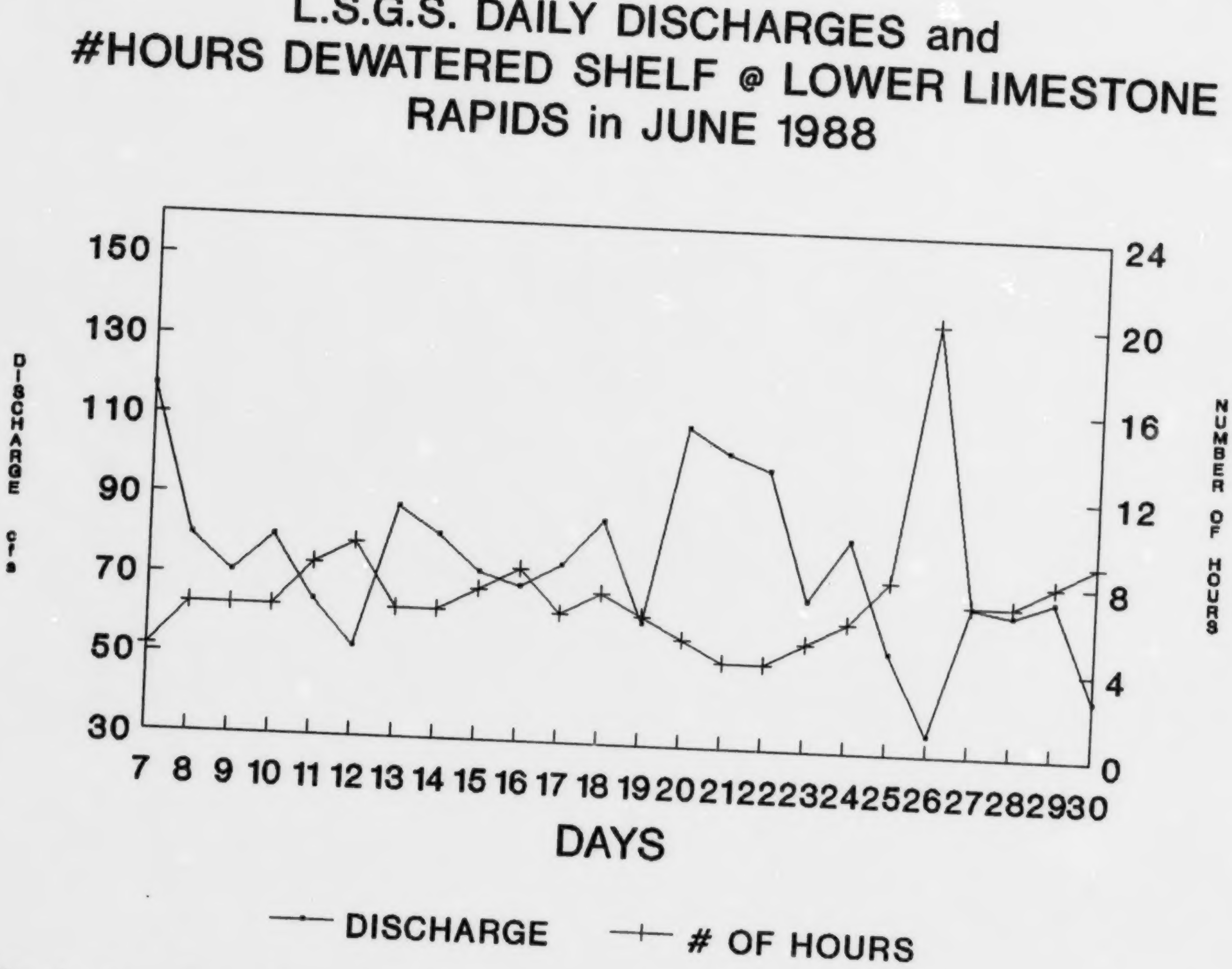

Fig. 6. Long Spruce Generating Station average daily discharges shown against the number of hours/day the lower Limestone Rapids had been partially dewatered in June, 1988.

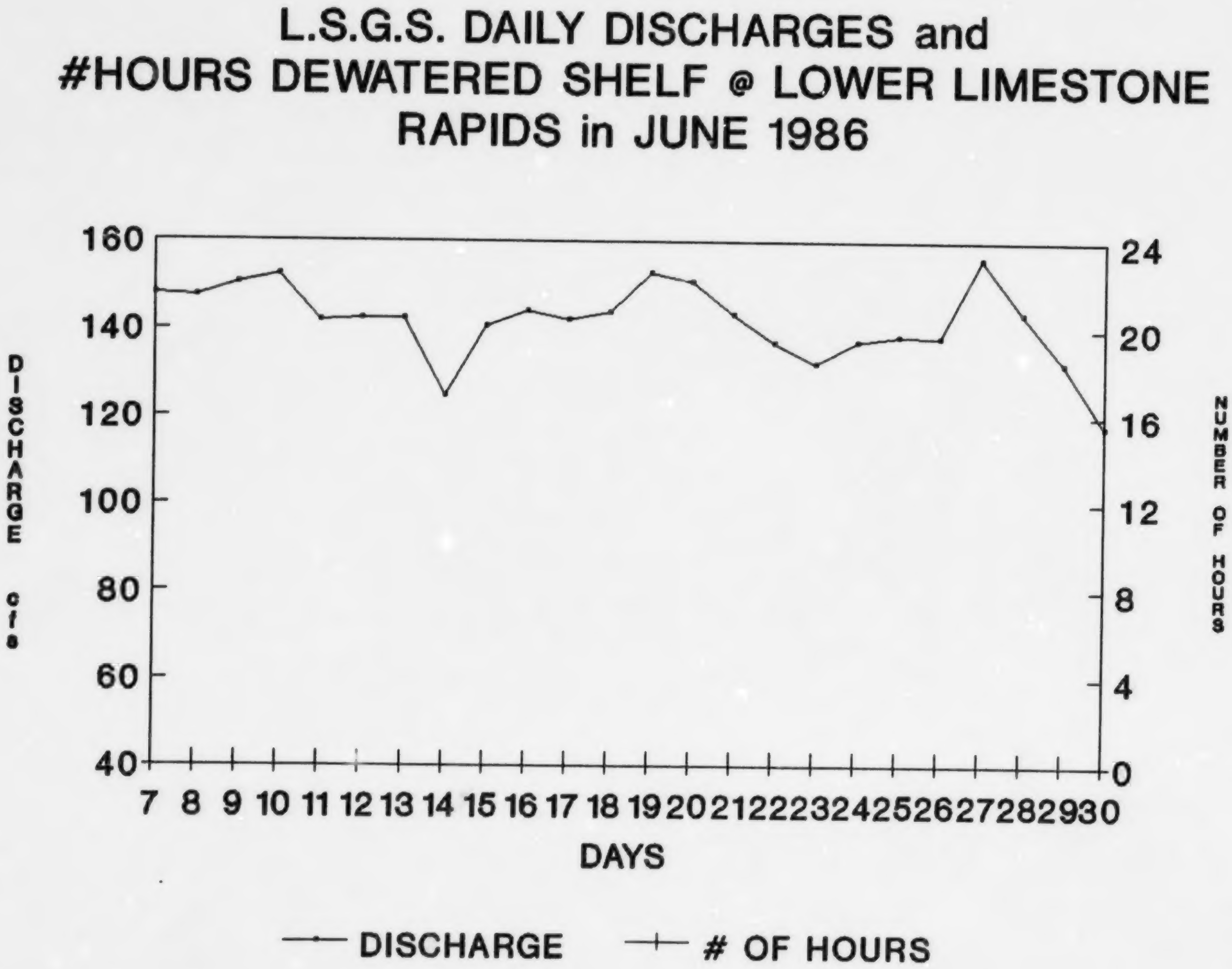

Fig. 7. Long Spruce Generating Station average daily discharges shown against the number of hours/day the lower Limestone Rapids had been partially dewatered in June, 1986.

least four hours of each reported day in June the rapids habitat was dewatered exposing the substrate.

As no young of the year sturgeon were caught in this study, and previous studies on the lower Nelson River since 1986 have not yielded any sturgeon younger than 11 years of age (Swanson and Kansas 1987; Swanson et al. 1988), all sturgeon captured since the project began in 1986 were combined and an age-frequency histogram was calculated (Figure 8). Subsequently, the periods of construction for the Kettle G.S. and the L.S.G.S and the drought of the "dirty thirties" period were overlayed on the same chart. No sturgeon produced since the end of the Kettle G.S. and the start of the L.S.G.S. have been found. There also appears to be a lack of older sturgeon originating from the 1930's drought years.

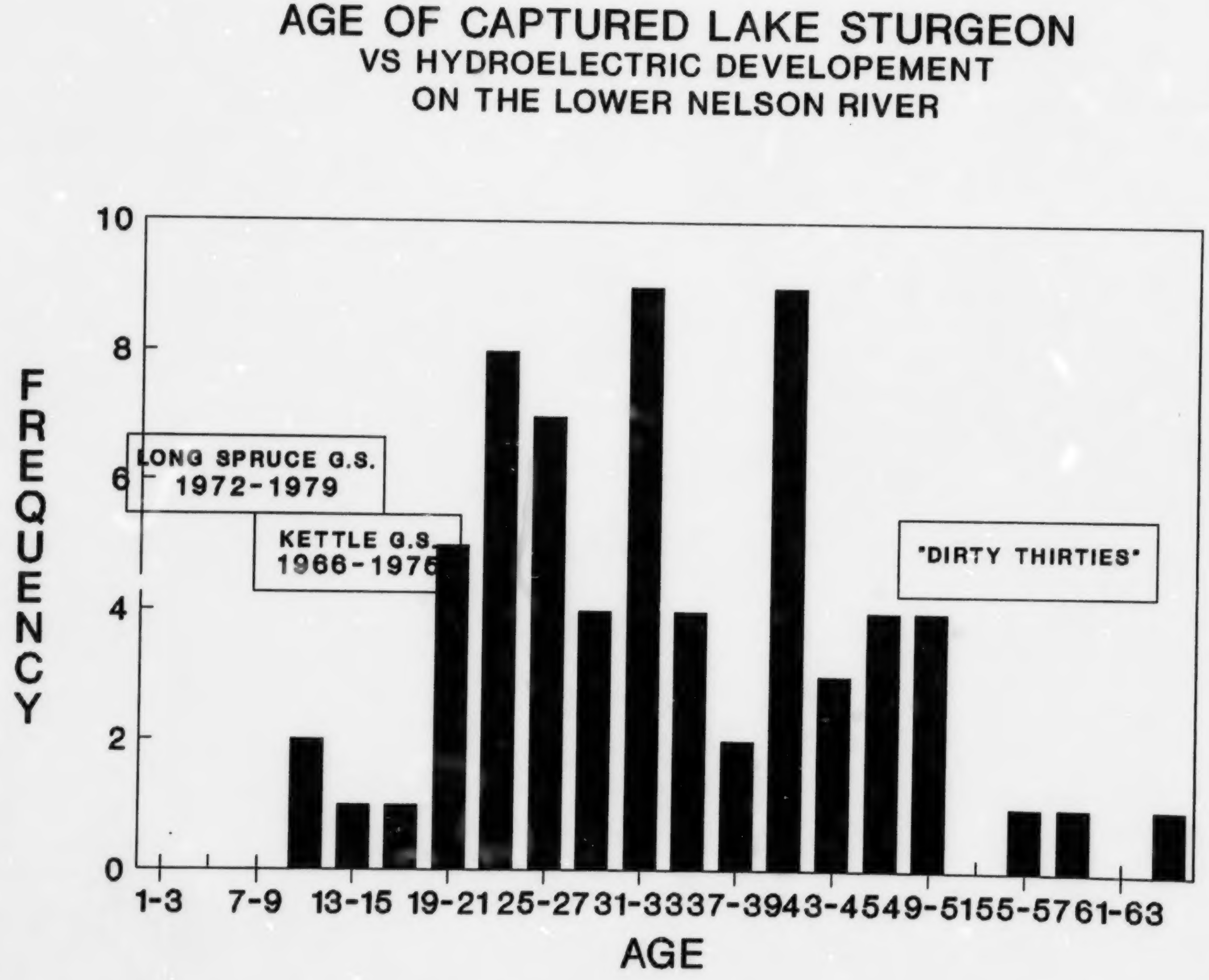

Fig. 8. Age frequency of captured lake sturgeon in the lower Nelson River from 1986-88 in relation to the hydroelectric development on the lower Nelson River.

DISCUSSION

Test Netting Conawapa Forebay

Studies in 1988 yielded very few sturgeon as in previous years (Swanson and Kansas 1987; Swanson et al.1988). In fact, fewer sturgeon were caught in 1988 than in 1986/87. This could be because most of the netting in 1986/87 was carried out several kilometres downstream of the 1988 site, in a less impacted (hydroelectric development) area of the lower Nelson River. As well, 1986 was a high water year which may have made it easier to sample fish (i.e. tributary mouths, where sturgeon tended to aggregate in the spring, were more extensively flooded). Radio telemetry data from 1986 (Swanson and Kansas 1987; Swanson et al. 1988), showed that sturgeon were most frequently located in those habitats least impacted by hydroelectric development (eg. estuary, Angling Lake).

Baseline data on the use of the different habitat types by fish species was typical of a river environment. The rapids produced the greatest number of species indicating the important contribution of rapids habitat to a riverine environment. The productivity that rapids habitat provides, including primary productivity, forage species and spawning habitat, is shown by the number of forage species and adult fish found (Hynes 1970). The tributary confluence sets showed peaks of northern pike in the spring. This is most likely due to spawning or post-spawning aggregations since this species spawns in the spring in rivers and creeks (Scott and Crossman 1973). The presence of young of the year pike in our seine hauls at this site supports this conclusion. Northern pike absence in the rapids habitat is probably related to swimming ability and the fact that pike prefer a slower riverine habitat (Scott and Crossman 1973). Peak numbers of ciscoes in the tributary confluence area in fall likely represent pre-spawning aggregations of this species which spawns in fall. Nelson River mainstem sets showed peaks of northern pike and goldeye in the summer. This could reflect post spawning foraging in the Nelson River proper. Patterson (1966) reports that goldeye move upstream to feed after spawning in the North Saskatchewan River. Longnose suckers, the most frequently caught in all sites, except tributary confluences, in the spring and summer, are the most prolific cypriniform in the north (Scott and Crossman 1973). The absence of longnose suckers at the tributary confluence site in the spring and summer is somewhat of a mystery. However, this site was located in a back water area with very little flow and longnose suckers prefer a riverine environment (Scott and Crossman 1973). Moreover, it is possible that this species was still upstream spawning during our spring sampling period.

The presence of young of the year walleye, whitefish, mooneye, yellow perch, northern pike, white suckers and longnose suckers indicates that these species spawn in the lower Nelson River and/or its' tributaries. However, the absence of adult mooneye and yellow perch is a mystery. Adult mooneye have been caught in the L.S. Reservoir (Swanson and Kansas 1987), and adult perch along with numerous young of the year have been caught in Angling Lake (Swanson et al. 1988). Perhaps pelagic young of the year mooneye and yellow perch migrated or were flushed out of the L.S. reservoir, especially since it is a run of the river reservoir as created by the L.S.G.S.. Scott (1955) reports seasonal migrations of yellow perch in Rondeau Bay of Lake Erie.

Differences in species composition between L.S. Reservoir and the lower Nelson River are not drastic. Greater numbers of walleye and sauger in L.S. Reservoir than the lower Nelson River are probably due to their preference for a large, turbid lake environment (Scott and Crossman 1973). Differences could also result from the fact that L.S. Reservoir is slower moving and hence easier to net in those areas which walleye and sauger are most likely to occupy. The reason for the absence of freshwater drum in the lower Nelson River sets is unknown. However, freshwater drum were angled by field staff in the test netting area (mouth of Moondance Creek).

In order to gain an understanding of seasonal fish requirements in the proposed Conawapa forebay in the lower Nelson River, additional baseline data are needed (i.e. repeat the netting program in the next few years). The L.S. Reservoir is similar to proposed generating station forebays in the lower Nelson River and could serve as a model for similar reservoirs resulting from future hydroelectric development of the lower Nelson River.

Lower Limestone Rapids

Sturgeon are known to spawn in areas of swift water or rapids with a gravel and boulder substrate (Scott and Crossman 1973). Such an area exists in the L.L.R. Since sturgeon have been seen "rolling" and breaking the surface in the spring of 1986 and 1988 in the same general area of the rapids, it is likely that they spawn in this reach. Recorded velocities in this area are consistent with velocities at which sturgeon spawn in the Wolf River in Wisconsin (Kempinger 1988). These sturgeon were also observed rolling and breaking the water surface at the spawning site in Wisconsin. Temperatures recorded in the L.L.R. when spawning was suspected are comparable to temperatures recorded during sturgeon spawning in Landing River, a tributary of the upper Nelson River (Sopuck 1987). Kempinger (1988) notes that sturgeon spawn quickly when they reach optimum temperature. This, combined with the effects of varying flows, might explain the fact that sturgeon were seen exhibiting spawning behaviour on only one day.

The authors believe that any eggs from sturgeon spawning in the L.L.R. during the spring of 1988 were exposed to air for 2-20 hours/day and would have become dessicated. Kempinger (1988) observed sturgeon eggs exposed to air during the ponding of water behind the Shawano Dam in Wisconsin. He also observed that eggs were dislodged from the substrate with a high increase in discharge from the dam. Actual discharge rates are not available but he did note a 32 cm increase in water depth at the study area between 0800 hours and midnight. Water levels at the L.L.R. during the sampling schedule in 1988 increased at least 100 cm (personal observations) over the same period of time. It is possible that similar if not more severe dislodging occurred if eggs were present. Nowak and McRitchie (1984) report that known and potential spawning areas for sturgeon were dewatered during June on the Frederick House River in Ontario and express the need for a critical minimum flow from hydro generating stations to protect spawning and nursery sites for sturgeon. Test netting in L.S. Reservoir in 1985/86 (Swanson and Kansas 1987) yielded no sturgeon, and only one sturgeon was caught during incidental netting. This fish was aged at 30+ years. These findings further indicate the negative impacts of hydroelectric development on sturgeon recruitment in the lower Nelson River.

The extreme variations in flow in the lower Nelson River appear to have a detrimental effect on sturgeon stocks. Figure 7 suggests that no successful sturgeon spawning has taken place in the lower Nelson River since the completion of the Kettle Generating Station. A minimum discharge of 45,000 c.f.s. from L.S.G.S. is required to water the L.L.R. in June during spawning and would also minimize large variations in flow that might dislodge sturgeon eggs. This minimum flow should facilitate a successful hatch. FMSC (1989) recommends a minimum discharge of 25,000 c.f.s. for the proposed Conawapa G.S. to protect the sensitive aquatic environment downstream. This figure was calculated using model simulation methods with no ground truthing. Detrimental effects of large water level fluctuations, the result of hydro generating stations, on sturgeon recruitment is well documented. Khoroshko (1972) reports an increase in spawning success of the Russian sturgeon (Acipenser stellatus), when discharge is regulated below dams in the U.S.S.R. Brousseau (1987) reports that decreased flow from dams in the Mattagami River in Ontario is the major limiting factor of sturgeon recruitment. Payne

(1987) reports negative effects of high fluctuations in water levels on sturgeon recruitment.

An alternative to a critical minimum flow for enhancing sturgeon spawning would be the possible creation of spawning areas immediately below hydro generating stations. There the long term effects of forebay ponding would not be as severe as in areas farther downstream, such as the L.L.R., where the loss of surface area is severe. A minimum discharge would still have to be maintained throughout the spawning season, but it would likely be lower than the minimum discharge needed to completely water the Lower Limestone Rapids. Swanson et al. (1988) report that a sturgeon was radio tagged below the L.S.G.S. and remained in the immediate vicinity for almost three years. The possibility exists that this sturgeon utilizes the area for forage and spawning. Sturgeon have been observed spawning below hydro dams in the Winnipeg River in a substrate of mainly boulders (Jim Beyette, Man. Dept. Nat. Res., pers. comm.). Sturgeon in Wisconsin spawn below dams and along the outside bends of rivers where rip rap is used to reinforce the banks (Priegal and Wirth 1971; Kempinger 1988; Folz et al. 1983). It might be feasible, during or after the completion of a generating station, to place large cobble and boulders below the tailrace section in areas where there would be continuous flow to create some artificial spawning habitat for sturgeon. This experimental mitigation activity is only recommended for the Limestone G.S. now under construction and only if it is the most downstream dam. The authors feel that if the Conawapa G.S. is built the resulting forebay would be too small to contain a viable sturgeon population therefore rendering the artificial spawning habitat ineffectual. If creation of such spawning habitat was considered more information would be needed to determine the effectiveness of such an undertaking. Monitoring of sturgeon spawning below the L.S.G.S. might provide such information.

Data presented in Figure 8 suggest that no successful spawning has occurred coincident with the completion of the Kettle and Long Spruce Generating Stations. The absence of sturgeon which are 11 years of age and younger in our sampling program might indicate that sampling was biased towards capture of larger older fish and that younger smaller sturgeon are not susceptible to capture in small-mesh gill nets. This is not so. Sandilands (1987) used small-mesh gill nets with good catch results for small sturgeon in the Kenogami River in Ontario. Small sturgeon are caught incidently in small-mesh gill nets by domestic fishermen in the Saskatchewan River (Bruce Wright, Man. Dept. Nat. Res., pers. comm.). Therefore, based on our sampling results, it must be assumed that sturgeon 11 years and younger are rare or absent in the study area. The lack of older sturgeon in Figure 8 may be due to the drought during the "dirty thirties" era. The extreme drought conditions of that time could have restricted recruitment through loss of important aquatic habitat. Sunde (1961) and Patalas (1988) both show a lack of older fish from this time period, however they offer no explanation. High commercial fishing pressure combined with the severe drought conditions may best explain these data.

CONCLUSIONS

1. Few sturgeon were captured during the test netting program; all were captured in the rapids habitat.

2. The rapids habitat was the most productive in terms of number of different species.

3. Walleye, northern pike, whitefish and mooneye young of the year were found in the study area.

4. Species compositions of the lower Nelson River and the L.S. Reservoir were not that different; L.S. Reservoir produced greater numbers of walleye and sauger and no sturgeon.

5. No sturgeon eggs or fry were found during the sampling of the Lower Limestone Rapids.

6. Sturgeon exhibited behaviour generally associated with spawning in the L.L.R. on June 18, 1988, during high discharge from the L.S.G.S. However, this area was dewatered from 2-20 hours/day throughout the month of June which would result in the desiccation of eggs.

7. L.S.G.S. average hourly discharge rates below 45,000 c.f.s. resulted in the dewatering of potential spawning

sites in the Lower Limestone Rapids.

8. It is possible that sturgeon have not spawned successfully in the lower Nelson River since the completion of the Kettle Generating Station.

RECOMMENDATIONS

1. The netting program in the proposed Conawapa forebay should be continued in order to increase baseline data.

2. Further investigations into sturgeon spawning should be conducted below the L.S.G.S. and at the L.L.R. in order to assess available and potential spawning habitat.

3. A minimum flow regime of 45,000 c.f.s. should be maintained at L.S.G.S. and the L.G.S. to provide watered rapids habitat throughout the month of June to protect sturgeon eggs from desiccation and scouring associated with rapidly varying flows.

4. The creation of artificial spawning habitat below dams in the Nelson River should be restricted to below the reservoir of the most downstream generating station on the system due to the small size of reservoirs created and the high flushing rates associated with them.

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APPENDICES

APPENDIX 1

Table 1. Results of detailed analysis of water samples from the Limestone River (W. M. Ward Technical Services Lab.).

Parameter	May 18/88	Jul 10/88	Mar 16/89
Conductivity (umhos/cm)	119	190	441
Total Residue (mg/l)	140	160	250
Filterable Residue (mg/l)	100	140	250
Non-filterable Residue (mg/l)	38	23	<5
pH	7.85	8.15	7.35
Tot. Alkalinity (CaCO3 mg/l)	60	100	222
Alkalinity (HCO3 mg/l)	73.2	122	271
Alkalinity (CO3 mg/l)	0	0	0
Alkalinity (OH mg/l)	0	0	0
Arsenic Extractable (mg/l)	<0.001	<0.001	<0.001
Cadmium Ext. (mg/l)	<0.001	<0.001	<0.001
Calcium Ext. (mg/l)	20.2	34.0	65.0
Magnesium Ext. (mg/l)	5.48	8.35	14.80
Hardness (mg/l)	73.0	119.0	225.0
Sodium Ext. (mg/l)	1.65	2.57	6.10
Potassium Ext. (mg/l)	<5.0	<5.0	<5.0
Copper Ext. (mg/l)	0.03	<0.01	0.01
Zinc Ext. (mg/l)	0.02	<0.01	<0.01
Iron Ext. (mg/l)	0.96	0.71	0.42
Manganese Ext. (mg/l)	0.05	0.06	<0.02
Lead Ext. (mg/l)	<0.005	<0.005	<0.005
Nickel Ext. (mg/l)	<0.005	<0.005	<0.005
True Colour (units)	>50	40	15
Turbidity (NTU)	11	13	1.82
Soluble Chloride (mg/l)	1.60	2.05	8
Soluble Sulphate (mg/l)	4.40	3.10	2.90

APPENDIX 1

Table 2. Results of detailed analysis of water samples from the Weir River (W. M. Ward Technical Services Lab.).

Parameter	May 18/88	Jul 10/88	Mar 16/89
Conductivity (umhos/cm)	103	145	472
Total Residue (mg/l)	260	140	290
Filterable Residue (mg/l)	90	120	280
Non-filterable Residue (mg/l)	170	18	10
pH	8.15	8.05	7.25
Tot. Alkalinity ($CaCO_3$ mg/l)	56.0	74.0	230
Alkalinity (HCO_3 mg/l)	68.3	90.3	281
Alkalinity (CO_3 mg/l)	0	0	0
Alkalinity (OH mg/l)	0	0	0
Arsenic Extractable (mg/l)	<0.001	<0.001	<0.001
Cadmium Ext. (mg/l)	<0.001	<0.001	<0.001
Calcium Ext. (mg/l)	31.2	26.9	68.9
Magnesium Ext. (mg/l)	8.53	6.15	15.1
Hardness (mg/l)	113	92.6	240
Sodium Ext. (mg/l)	1.18	2.38	9.51
Potassium Ext. (mg/l)	<5.0	<5.0	<5.0
Copper Ext. (mg/l)	0.03	<0.01	0.02
Zinc Ext. (mg/l)	0.02	<0.01	<0.01
Iron Ext. (mg/l)	2.30	0.67	0.77
Manganese Ext. (mg/l)	0.10	0.04	0.06
Lead Ext. (mg/l)	<0.005	<0.005	<0.005
Nickel Ext. (mg/l)	<0.005	<0.005	<0.005
True Colour (units)	>50	>50	20
Turbidity (NTU)	57	5.2	2.1
Soluble Chloride (mg/l)	2	2.20	10
Soluble Sulphate (mg/l)	3.90	3.90	2.75

APPENDIX 1

Table 3. Results of detailed analysis of water samples from the Angling River (W. M. Ward Technical Services Lab.).

Parameter	May 18/88	Jul 10/88	Mar 16/89
Conductivity (umhos/cm)	81.5	130	401
Total Residue (mg/l)	140	110	130
Filterable Residue (mg/l)	76	110	120
Non-filterable Residue (mg/l)	64	<5	6
pH	7.95	8.20	7.05
Tot. Alkalinity (CaCO3 mg/l)	42	66	200
Alkalinity (HCO3 mg/l)	51.2	80.5	244
Alkalinity (CO3 mg/l)	0	0	0
Alkalinity (OH mg/l)	0	0	0
Arsenic Extractable (mg/l)	<0.001	<0.001	<0.001
Cadmium Ext. (mg/l)	<0.001	<0.001	<0.001
Calcium Ext. (mg/l)	22	20.5	60.9
Magnesium Ext. (mg/l)	5.36	4.20	11.3
Hardness (mg/l)	77.1	68.6	198
Sodium Ext. (mg/l)	1.68	2.36	7.42
Potassium Ext. (mg/l)	<5.0	<5.0	<5.0
Copper Ext. (mg/l)	<0.01	<0.01	<0.01
Zinc Ext. (mg/l)	<0.01	<0.01	<0.01
Iron Ext. (mg/l)	1.29	0.15	0.22
Manganese Ext. (mg/l)	0.05	<0.02	<0.02
Lead Ext. (mg/l)	<0.005	<0.005	<0.005
Nickel Ext. (mg/l)	<0.005	<0.005	<0.005
True Colour (units)	>50	50	>50
Turbidity (NTU)	18	0.58	5.4
Soluble Chloride (mg/l)	1.60	1.65	8
Soluble Sulphate (mg/l)	3.40	3.00	2.75

APPENDIX 1

Table 4. Results of detailed analysis of water samples from the Kaiskwasotasine River (W. M. Ward Technical Services Lab.).

Parameter	May 18/88	Jul 10/88	Mar 16/89
Conductivity (umhos/cm)	63.3	92.9	304
Total Residue (mg/l)	250	120	220
Filterable Residue (mg/l)	90	100	210
Non-filterable Residue (mg/l)	160	19	12
pH	7.90	7.90	6.60
Tot. Alkalinity (CaCO3 mg/l)	32	46	140
Alkalinity (HCO3 mg/l)	39	56.1	171
Alkalinity (CO3 mg/l)	0	0	0
Alkalinity (OH mg/l)	0	0	0
Arsenic Extractable (mg/l)	<0.001	<0.001	<0.001
Cadmium Ext. (mg/l)	<0.001	<0.001	<0.001
Calcium Ext. (mg/l)	30.1	17.2	43.6
Magnesium Ext. (mg/l)	9.40	3.97	7.60
Hardness (mg/l)	114	59.3	141
Sodium Ext. (mg/l)	1.65	2.44	4.94
Potassium Ext. (mg/l)	<5.0	<5.0	<5.0
Copper Ext. (mg/l)	0.04	<0.01	0.08
Zinc Ext. (mg/l)	0.02	<0.01	0.06
Iron Ext. (mg/l)	2.04	0.80	4.36
Manganese Ext. (mg/l)	0.11	0.02	1.34
Lead Ext. (mg/l)	<0.005	<0.005	0.014
Nickel Ext. (mg/l)	<0.005	<0.005	<0.005
True Colour (units)	>50	>50	>50
Turbidity (NTU)	49	5.0	7.5
Soluble Chloride (mg/l)	1.60	1.85	5
Soluble Sulphate (mg/l)	3.10	4.60	15

APPENDIX 2

Calculation of Daily Temperature Units to March 14, 1989 at each study site, and requirements for hatching of brook trout eggs at comparable temperatures.

One Daily Temperature Unit (DTU) = 1°F above 32°F for 24 hours.

Incubation Period: September 24, 1988 - March 14, 1989 = 171 days

Stream	Incubation Temperature (F) Jan 25/89	°F above 32	DTU
CN	41.7	9.7	1658.7
Wilson	39.4	7.4	1265.4
9-Mile	36.1	4.1	701.1

DTU required to hatch brook trout eggs @ 35°F = 432[a]
@ 40°F = 824
@ 45°F = 884

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[a] from Piper et al. (1982).

APPENDIX 3

Table 1. Numbers of dead eggs of various appearances from baskets in 9-Mile and Wilson creeks.

9-M1	9-M2	9-M3
Eyed = 24	Eyed = 2	Some Development = 11
No Eyes = 17	No Eyes = 158	No eyes = 114
Opaque = 159	Opaque = 38	Opaque = 78

W1	W2	W3
Eyed = 75	Opaque = 92	Opaque = 175
Opaque = 45	Black = 102	Some Development = 20
Crushed = 35		
Black = 176		

APPENDIX 4

Chi-square tests for equal development among CN Creek baskets.

- Chi-square test for equal development among CN1, CN2 and CN3.

	DEVELOPMENT			
	# Dead Eggs	# Dead Fry	# Live Fry	Total
OBSERVED				
CN1	39	12	149	200
CN2	54	5	141	200
CN3	109	0	91	200
Total	202	17	381	600
EXPECTED				
CN1	67.3	5.7	127	200
CN2	67.3	5.7	127	200
CN3	67.3	5.7	127	200
Total	201.9	17.1	381	600
DEVIATIONS				
CN1	-28.3	6.3	22	0.0
CN2	-13.3	-0.7	14	0.0
CN3	41.7	-5.7	-36	0.0

Chi-square = 68.67 Chi-square (P=.05, d.f.=4) = 9.49

- Chi-square test for equal development between CN1 and CN2.

	DEVELOPMENT			
	# Dead Eggs	# Dead Fry	# Live Fry	Total
OBSERVED				
CN1	39	12	149	200
CN2	54	5	141	200
Total	93	17	290	400
EXPECTED				
CN1	46.5	8.5	145	200
CN2	46.5	8.5	145	200
Total	93	17	290	400
DEVIATIONS				
CN1	-7.5	3.5	4	0.0
CN2	7.5	-3.5	-4	0.0

Chi-square = 5.52 Chi-square (P=.05, d.f.=2) = 5.99

- Chi-square test for equal development between CN3 and the combined data of CN1 and CN2.

	DEVELOPMENT			
	# Dead Eggs	# Dead Fry	# Live Fry	Total
OBSERVED				
CN1&CN2	93	17	290	400
CN3	109	0	91	200
Total	202	17	381	600
EXPECTED				
CN1&CN2	134.7	11.3	254	400
CN3	67.3	5.7	127	200
Total	202	17	381	600
DEVIATIONS				
CN1&CN2	-41.7	5.7	36	0.0
CN3	41.7	-5.7	-36	0.0

Chi-square = 62.62 Chi-square (P=.05, d.f.=2) = 5.99

APPENDIX 5

Measurements of brook trout fry from CN Creek baskets.

BROOK TROUT FRY MEASUREMENTS
SAMPLE CN 1

FRY NUMBER	TOTAL LENGTH (mm)	YOLK LENGTH (mm)	YOLK DEPTH (mm)	YOLK WIDTH (mm)
1	21.0	5.04	1.73	2.83
2	21.0	5.51	1.73	2.83
3	22.0	4.72	1.73	2.68
4	23.0	5.35	1.73	2.83
5	22.5	5.51	1.73	2.83
6	21.0	5.35	1.89	2.68
7	21.5	5.20	1.42	2.68
8	21.0	5.04	1.89	2.83
9	22.0	5.51	1.57	2.68
10	22.0	5.04	1.73	2.83
11	22.5	5.04	1.73	2.83
12	23.0	5.04	1.42	2.52
13	22.0	5.51	1.57	2.83
14	22.0	5.35	1.89	2.68
15	23.0	5.20	1.73	2.99
16	21.0	5.20	1.73	2.83
17	21.0	5.04	1.57	2.83
18	22.0	5.35	2.05	2.83
19	22.0	4.72	1.26	2.83
20	22.0	4.88	1.42	2.68
21	21.0	4.88	1.73	2.83
22	22.0	4.57	1.57	2.83
23	22.5	5.04	1.57	2.99
24	21.0	4.41	1.57	2.68
25	22.0	5.83	1.89	2.68
26	21.5	5.04	1.73	2.83
27	21.0	5.04	2.05	2.83
28	23.0	5.51	1.89	2.83
29	22.5	5.04	4.41	2.52
30	23.5	5.35	1.73	2.83
31	22.0	5.67	1.89	2.83
32	22.5	5.35	1.57	2.52
33	22.0	5.67	1.26	2.83
34	23.0	5.35	1.57	2.68
35	21.5	4.88	1.57	2.68
36	22.0	5.20	1.57	2.83
37	20.0	4.72	1.73	2.68
38	23.0	5.04	2.05	2.99
39	22.0	5.35	1.73	2.68
40	23.5	5.67	1.42	2.83

BROOK TROUT FRY MEASUREMENTS
SAMPLE CN 1

FRY NUMBER	TOTAL LENGTH (mm)	YOLK LENGTH (mm)	YOLK DEPTH (mm)	YOLK WIDTH (mm)
41	21.0	4.57	1.73	2.83
42	21.0	5.04	1.57	2.83
43	21.0	4.88	1.42	2.68
44	20.5	4.72	1.73	2.99
45	21.5	4.88	1.42	2.68
46	22.4	4.57	1.73	2.83
47	22.5	5.04	1.42	2.68
48	22.0	5.20	1.57	2.68
49	21.0	5.04	1.73	2.83
50	22.5	5.04	1.73	2.83
51	21.5	4.57	1.26	2.52
52	22.0	5.04	1.73	2.52
53	21.5	5.20	1.26	2.36
54	21.0	4.57	1.26	2.99
55	21.5	5.51	1.57	2.68
56	21.0	4.72	1.09	2.68
57	23.0	5.35	1.26	2.68
58	22.5	5.20	1.57	3.15
59	21.0	4.88	1.26	2.68
60	22.0	5.04	1.89	2.99
61	22.0	5.04	1.42	2.52
62	22.0	5.35	1.73	2.68
63	22.0	5.20	1.42	2.68
64	21.0	5.04	1.42	2.68
65	23.0	5.20	1.26	2.83
66	21.0	4.88	1.42	2.83
67	24.0	5.67	1.10	2.83
68	23.0	5.04	1.42	2.52
69	23.5	5.35	1.57	2.68
70	22.0	5.35	1.57	2.83
71	22.0	5.20	1.42	2.83
72	21.0	4.88	1.42	2.52
73	21.0	4.88	1.42	2.83
74	22.0	4.88	1.42	2.83
75	22.5	4.72	0.94	2.68
76	22.5	4.88	1.26	2.83
77	20.5	4.88	1.42	2.83
78	21.5	4.57	0.79	2.68
79	22.0	5.51	1.42	2.68
80	22.0	5.35	1.57	2.83

BROOK TROUT FRY MEASUREMENTS
SAMPLE CN 1

FRY NUMBER	TOTAL LENGTH (mm)	YOLK LENGTH (mm)	YOLK DEPTH (mm)	YOLK WIDTH (mm)
81	22.5	5.35	1.73	2.68
82	21.5	4.88	1.42	2.83
83	21.0	5.04	1.57	2.68
84	22.5	5.04	1.42	2.52
85	21.5	4.72	1.42	2.83
86	21.0	4.88	1.26	2.83
87	22.0	5.04	1.57	2.68
88	22.5	5.04	1.42	2.83
89	22.0	4.72	1.42	2.68
90	22.0	4.88	1.42	2.68
91	21.0	5.35	1.57	2.83
92	23.0	5.04	1.42	2.52
93	21.0	5.04	1.73	2.52
94	21.5	5.04	1.26	2.68
95	23.0	5.35	1.57	2.83
96	22.5	5.04	1.57	2.83
97	21.5	4.72	1.26	2.83
98	23.0	5.04	1.89	2.83
99	21.5	5.04	1.26	2.83

BROOK TROUT FRY MEASUREMENTS
SAMPLE CN 2

FRY NUMBER	TOTAL LENGTH (mm)	YOLK LENGTH (mm)	YOLK DEPTH (mm)	YOLK WIDTH (mm)
1	22.5	5.51	1.42	2.52
2	21.5	5.04	1.57	2.68
3	21.5	5.20	1.57	2.68
4	22.5	5.35	1.57	2.83
5	22.0	5.35	2.36	2.99
6	23.5	5.83	1.42	2.99
7	22.0	4.72	1.73	2.68
8	21.0	5.35	1.73	2.52
9	21.0	5.67	2.05	2.68
10	20.5	5.20	2.20	2.83
11	22.0	5.98	1.73	2.83
12	20.5	5.20	1.57	2.83
13	21.0	6.14	1.73	2.68
14	22.0	5.20	1.89	2.68
15	20.0	5.67	2.36	2.99
16	22.0	5.20	1.89	2.52
17	21.5	5.35	2.20	2.68
18	22.0	5.35	1.89	2.83
19	21.0	5.35	2.36	2.99
20	21.5	5.83	1.73	2.99
21	21.0	4.88	2.05	2.83
22	21.0	5.04	2.05	2.99
23	23.0	5.98	1.57	2.68
24	20.5	5.04	1.73	2.36
25	22.0	5.83	1.57	2.68
26	22.5	5.35	1.57	2.36
27	21.5	5.04	1.26	2.36
28	21.0	5.04	2.05	3.15
29	20.5	4.88	1.73	2.83
30	21.0	5.20	1.73	2.52
31	20.5	5.20	1.89	2.83
32	21.0	5.04	1.73	2.68
33	19.5	5.35	2.20	2.83
34	21.5	5.20	1.57	2.83
35	21.0	5.20	2.20	2.52
36	21.0	5.20	2.20	2.99
37	19.5	5.35	2.20	2.83
38	21.0	5.67	1.73	2.99
39	21.0	5.35	2.05	2.68
40	23.0	5.98	1.73	2.83

BROOK TROUT FRY MEASUREMENTS
SAMPLE CN 2

FRY NUMBER	TOTAL LENGTH (mm)	YOLK LENGTH (mm)	YOLK DEPTH (mm)	YOLK WIDTH (mm)
41	23.0	4.88	1.42	2.83
42	22.0	5.98	1.57	2.68
43	20.5	5.04	1.73	2.68
44	21.0	5.04	2.05	2.83
45	22.5	5.51	1.73	2.83
46	21.5	5.35	1.73	2.83
47	22.0	5.04	2.05	2.52
48	21.5	5.35	1.89	2.52
49	21.0	5.83	1.89	2.83
50	22.0	5.20	2.05	2.68
51	21.0	5.35	1.89	2.68
52	22.0	5.35	2.20	2.83
53	20.5	5.20	1.73	2.68
54	21.0	4.88	1.73	2.52
55	22.5	5.20	1.89	2.83
56	20.0	5.20	2.05	2.68
57	21.5	5.35	1.57	2.99
58	21.0	4.88	1.89	2.52
59	21.5	5.04	1.89	2.68
60	21.5	5.51	1.57	2.36
61	21.5	5.35	1.73	2.99
62	19.5	5.51	2.36	2.83
63	21.0	5.04	1.73	2.83
64	22.5	5.20	1.89	2.99
65	21.0	5.67	2.52	2.99
66	20.5	5.20	1.89	2.99
67	22.5	5.35	2.20	2.83
68	22.0	5.35	1.73	2.99
69	21.0	5.20	2.20	2.83
70	21.0	5.35	2.36	2.83
71	21.0	4.72	1.42	2.36
72	23.0	5.83	1.89	2.52
73	21.0	5.20	1.89	2.68
74	21.5	5.98	1.57	2.83
75	21.0	5.04	2.05	2.52
76	20.0	5.20	2.36	2.99
77	21.0	5.20	2.05	2.83
78	22.0	5.04	1.57	2.68
79	20.5	5.51	2.20	2.83
80	20.0	5.67	2.52	2.83

BROOK TROUT FRY MEASUREMENTS
SAMPLE CN 2

FRY NUMBER	TOTAL LENGTH (mm)	YOLK LENGTH (mm)	YOLK DEPTH (mm)	YOLK WIDTH (mm)
81	22.0	5.35	1.57	2.68
82	22.0	5.04	1.73	2.68
83	22.5	5.04	1.57	2.83
84	22.5	5.20	1.73	2.99
85	22.0	5.04	1.89	2.83
86	22.5	5.20	1.89	2.99
87	21.0	4.88	1.73	2.52
88	20.5	5.98	2.20	2.99
89	20.0	6.14	2.68	3.15
90	21.0	5.51	1.73	2.68
91	21.0	5.35	1.73	2.83

BROOK TROUT FRY MEASUREMENTS
SAMPLE CN 3

FRY NUMBER	TOTAL LENGTH (mm)	YOLK LENGTH (mm)	YOLK DEPTH (mm)	YOLK WIDTH (mm)
1	20.5	5.67	1.57	2.99
2	20.0	5.04	1.73	2.83
3	20.0	5.67	2.36	2.99
4	19.0	5.20	2.36	3.15
5	20.0	5.04	1.57	2.99
6	21.5	5.20	1.57	2.83
7	18.5	5.83	2.83	2.99
8	21.0	6.30	2.20	2.68
9	22.5	5.98	1.42	3.15
10	21.0	5.04	1.89	2.83
11	21.5	6.61	2.36	3.15
12	20.0	5.20	2.36	2.83
13	19.5	5.04	2.05	2.83
14	20.5	5.04	2.05	2.83
15	21.0	5.04	1.73	2.83
16	21.5	5.20	2.20	2.99
17	22.0	5.20	1.89	2.83
18	20.5	4.88	1.89	2.68

APPENDIX 6

Analysis of Variance tables and F statistics for measurements of brook trout fry in baskets CN1, CN2 and CN3.

Analysis of Variance - Total Fry Length

Source	d.f.	S.S.	M.S.
Among Baskets	2	21.79	10.89
Within Baskets	51	45.81	0.90
Total	53	67.60	11.79

F = 12.13 ; F(.01,2,51) = 3.1504

Analysis of Variance - Yolk Depth

Source	d.f.	S.S.	M.S.
Among Baskets	2	1.94	0.97
Within Baskets	51	4.80	0.09
Total	53	6.74	1.06

F = 10.29 ; F(.01,2,51) = 3.1504

Analysis of Variance - Yolk Width

Source	d.f.	S.S.	M.S.
Among Baskets	2	0.36	0.18
Within Baskets	51	1.02	0.02
Total	53	1.38	0.20

F = 8.91 ; F(.01,2,51) = 3.1504

Analysis of Variance - Yolk Length

Source	d.f.	S.S.	M.S.
Among Baskets	2	1.79	0.89
Within Baskets	51	6.87	0.13
Total	53	8.66	1.02

F = 6.64 ; F(.01,2,51) = 3.1504

APPENDIX 7

Results of U.S. Standard Sieve analyses of substrate samples from within baskets CN1, 2, & 3 and from the sediment deposited above the baskets (B1).

DEPARTMENT OF NATURAL RESOURCES ENGINEERING & CONSTRUCTION BRANCH
TECHNICAL LABORATORY
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SIEVE OR SCREEN ANALYSIS OF FINE AND COARSE AGGREGATES
A.S.T.M. C-117 , C-136

PROJECT :	FISHERIES	TECH. :	R.W.
12MAY88 LOCATION/PLAN :	PLASTIC BAG	CHECKED:	J.B.

****

LAB.NUMBER: 8998 FIELD NO:B-1

HOLE NO.:

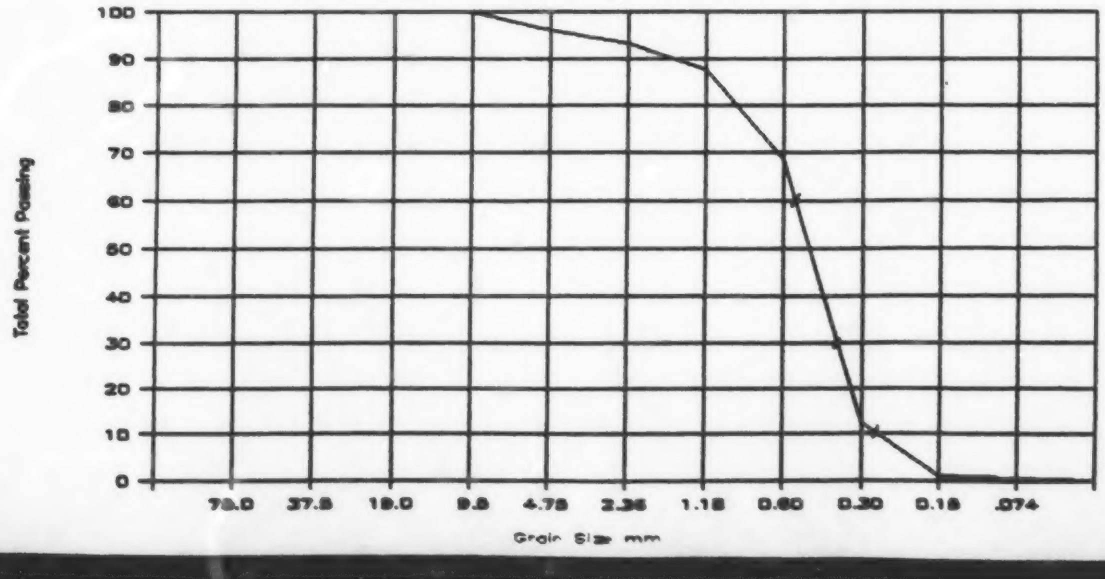
DEPTH(M):

Mass of Sample Before Washing	209.50
Mass of Sample after Washing	208.60
Mass Passing 0.074(200) (wash)	0.90
Mass Passing .074 (200) (sieve)	0.20
Mass Total Passing .074 (200)	1.10

Sieve U.S stan.	Size m.m	Mass Retained Basis Total Sample	Retained (%)	Cumulative Retained (%)	Cumulative Passing (%)
					100.00
3.00	75.0		0.00	0.00	100.00
1.50	37.5		0.00	0.00	.100.00
.750	19.0		0.00	0.00	100.00
.375	9.5		0.00	0.00	100.00
NO.4	4.75	8.10	3.87	3.87	96.13
8	2.36	6.10	2.91	6.78	93.22
16	1.18	11.50	5.49	12.27	87.73
30	0.60	40.30	19.24	31.50	68.50
50	0.30	117.30	55.99	87.49	12.51
100	0.15	23.90	11.41	98.90	1.10
200	.074	1.20	0.57	99.47	0.53
PAN	0.00	1.10	0.53	100.00	0.00
Total		209.50	100.00		

% Pass.074	% Sand=	% Gravel=	F.M.=
0.53	95.61	3.87	2.41

U.S Standard Sieve Series A.S.T.M E11



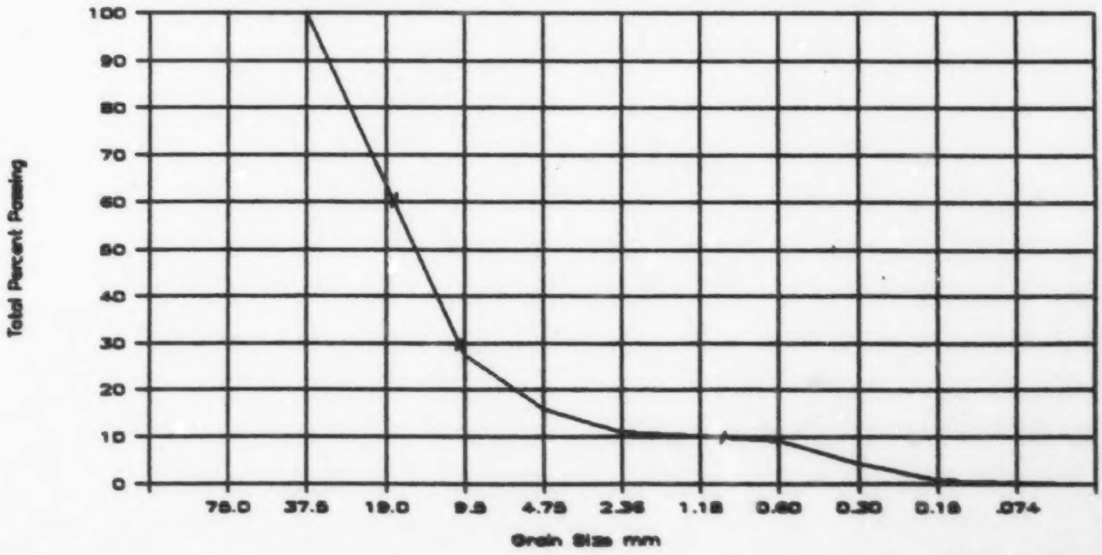
LAB.NUMBER: 8999 FIELD NO:CN-1 HOLE NO.:
DEPTH(M):

Mass of Sample Before Washing	741.20
Mass of Sample after Washing	740.20
Mass Passing 0.074(200) (wash)	1.00
Mass Passing .074 (200) (sieve)	1.20
Mass Total Passing .074 (200)	2.20

Sieve U.S stan.	Size m.m	Mass Retained Basis Total Sample	Retained (%)	Cumulative Retained (%)	Cumulative Passing (%)
					100.00
3.00	75.0		0.00	0.00	100.00
1.50	37.5		0.00	0.00	100.00
.750	19.0	270.20	36.45	36.45	63.55
.375	9.5	269.10	36.31	72.76	27.24
NO.4	4.75	82.60	11.14	83.90	16.10
8	2.36	37.30	5.03	88.94	11.06
16	1.18	4.80	0.65	89.58	10.42
30	0.60	7.60	1.03	90.61	9.39
50	0.30	36.80	4.96	95.57	4.43
100	0.15	27.00	3.64	99.22	0.78
200	.074	3.60	0.49	99.70	0.30
PAN	0.00	2.20	0.30	100.00	0.00
Total		741.20	100.00		

% Pass.074	% Sand=	% Gravel=	F.M.=
0.30	15.80	83.90	6.57

U.S Standard Sieve Series A.S.T.M E11



****

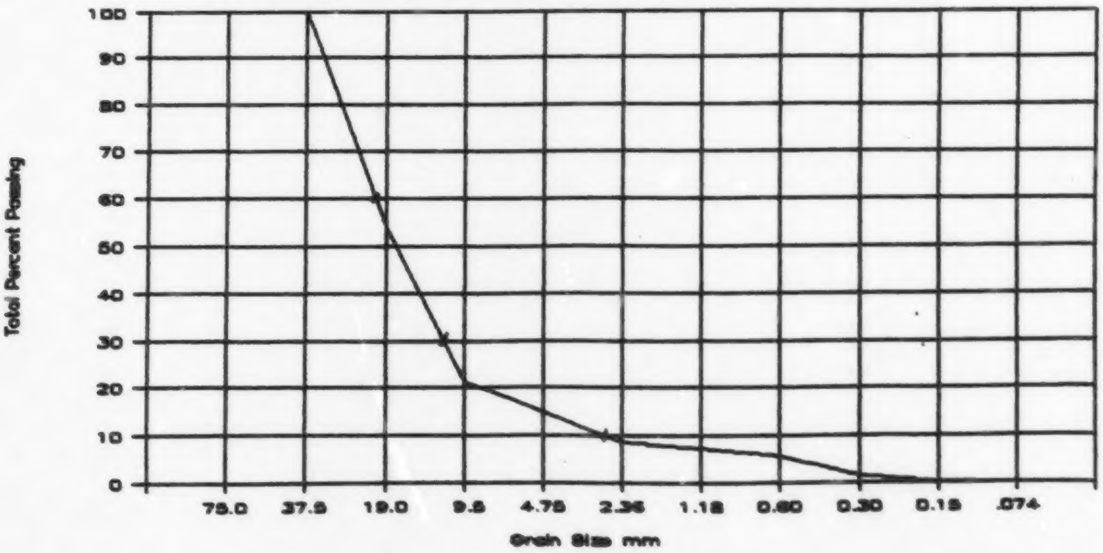
LAB.NUMBER: 9000 FIELD NO:CN-2 HOLE NO.:
DEPTH(M):

Mass of Sample Before Washing	750.30
Mass of Sample after Washing	750.00
Mass Passing 0.074(200) (wash)	0.30
Mass Passing .074 (200) (sieve)	0.80
Mass Total Passing .074 (200)	1.10

Sieve U.S stan.	Size m.m	Mass Retained Basis Total Sample	Retained (%)	Cumulative Retained (%)	Cumulative Passing (%)
					100.00
3.00	75.0		0.00	0.00	100.00
1.50	37.5		0.00	0.00	100.00
.750	19.0	345.30	46.02	46.02	53.98
.375	9.5	244.20	32.55	78.57	21.43
NO.4	4.75	48.20	6.42	84.99	15.01
8	2.36	46.00	6.13	91.12	8.88
16	1.18	10.20	1.36	92.48	7.52
30	0.60	12.00	1.60	94.08	5.92
50	0.30	31.80	4.24	98.32	1.68
100	0.15	9.90	1.32	99.64	0.36
200	.074	1.60	0.21	99.85	0.15
PAN	0.00	1.10	0.15	100.00	0.00
Total		750.30	100.00		

% Pass.074	% Sand=	% Gravel=	F.M.=
0.15	14.86	84.99	6.85

U.S Standard Sieve Series A.S.T.M E11



12-May-89

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LAB.NUMBER:	9001 FIELD NO:CN-3	HOLE NO.:	
		DEPTH(M):	

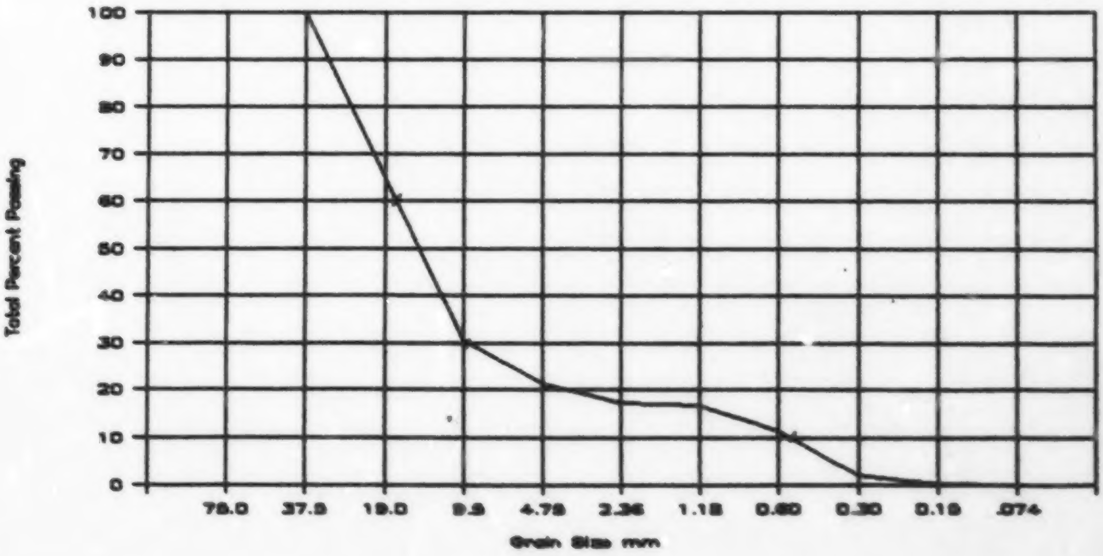
Mass of Sample Before Washing	792.80
Mass of Sample after Washing	792.00
Mass Passing 0.074(200) (wash)	0.80
Mass Passing .074 (200) (sieve)	0.20
Mass Total Passing .074 (200)	1.00

==

Sieve U.S stan.	Size m.m	Mass Retained Basis Total Sample	Retained (%)	Cumulative Retained (%)	Cumulative Passing (%)
					100.00
3.00	75.0		0.00	0.00	100.00
1.50	37.5		0.00	0.00	100.00
.750	19.0	278.70	35.15	35.15	64.85
.375	9.5	274.10	34.57	69.73	30.27
NO.4	4.75	71.40	9.01	78.73	21.27
8	2.36	31.50	3.97	82.71	17.29
16	1.18	3.20	0.40	83.11	16.89
30	0.60	41.50	5.23	88.35	11.65
50	0.30	74.80	9.43	97.78	2.22
100	0.15	16.00	2.02	99.80	0.20
200	.074	0.60	0.08	99.87	0.13
PAN	0.00	1.00	0.13	100.00	0.00
Total		792.80	100.00		

% Pass.074	% Sand=	% Gravel=	F.M.=
0.13	21.14	78.73	6.35

U.S Standard Sieve Series A.S.T.M E11



APPENDIX 8

Tagging history of recaptured brook trout in the Nelson River study area.

1985-88 Brook Trout recapture summary

Tagnumber	Date	Location
48.371	23.09.85	SKY PILOT CK. @ MOUTH
	5.12.85	GILLAM TOWNSITE, NO INFO
48.399	20.09.85	LIMESTONE R. @ 5-MILE HOLE
	9.10.85	LIMESTONE R. @ 5-MILE HOLE, TURNED INTO C.O'S
48.454	12.09.85	LIMESTONE R. @ 5-MILE HOLE
	8.10.85	LIMESTONE R. @ 5-MILE HOLE (RELEASED)
I001006	3.08.87	CN CK.,1/2KM ABOVE CULVERTS
	8.09.87	CN CK. FOUND DEAD 100M BELOW FENCE #1
I001012	3.08.87	CN CK.,1/2KM ABOVE CULVERTS
	11.09.87	CN CK.
I001039	1.10.86	LIMESTONE R. @ 5-MILE HOLE
		-SUMMER-
I001043	28.08.86	LIMESTONE R. @ 5-MILE HOLE
	1.10.87	LIMESTONE R. @ 5-MILE HOLE NO OTHER INFO.
I001052	1.10.87	12-MILE CK.
	17.10.87	12-MILE CK.,100M ABOVE FENCE
	9.08.88	12-MILE CK. BESIDE AN UNMARKED CREEK
I001061	2.10.87	9-MILE CK.
	13.10.88	9-MILE CK.
I001063	3.10.87	9-MILE CK.,JUST ABOVE FENCE
	16.09.88	9-MILE CK.
I001066	3.10.87	9-MILE CK.
	19.08.88	LIMESTONE R.
I001075	3.06.87	MOONDANCE CK.
	29.08.87	MOONDANCE CK. @ MOUTH
I001080	9.09.86	LIMESTONE R. @ 5-MILE HOLE
	16.08.87	BIRD CK. @ MOUTH, R. BEARDY
I001104	3.10.87	9-MILE CK.
	29.09.88	9-MILE CK.
I001107	3.10.87	9-MILE CK.
	13.10.88	9-MILE CK.

I001110	3.10.87	9-MILE CK.
	25.09.88	9-MILE CK.
I001119	4.10.87	9-MILE CK.
	13.10.88	9-MILE CK.
I001172	12.10.87	WILSON CK.
	18.08.88	WILSON CK. F-PIT AREA
I001173	12.10.87	WILSON CK.
	4.07.88	WILSON CK.
I001174	12.10.87	WILSON CK.
	22.05.88	WILSON CK.
I001181	13.10.87	WILSON CK.
	10.07.88	SKY PILOT CK.
I001185	13.10.87	WILSON CK.
	13.10.88	WILSON CK.
I001190	14.10.87	WILSON CK.
	18.08.88	WILSON CK.
I001202	7.10.87	9-MILE CK.
	26.07.88	WILSON CK.
I001206	11.10.87	12-MILE CK.
	12.08.86	12-MILE CK. D/S OF CAMP
I001207	11.10.87	12-MILE CK.
	8.06.88	12-MILE CK. BELOW QUADRANT #4
	16.10.88	12-MILE CK. 100m U/S FROM FENCE
I001220	15.10.87	12-MILE CK.,100M ABOVE FENCE
	17.10.87	12-MILE CK.,100M ABOVE FENCE
	3.10.88	12-MILE CK. ABOVE DOWN TRAP
I001226	15.07.88	CN CK.HABITAT SEC.#1
	4.08.88	CN CK. HABITAT SEC#1
I001227	15.07.88	CN CK. HABITAT SEC.#3
	29.08.88	CN CK. POP. ESTIMATE SEC.
I001229	8.08.88	CN CK. POP. ESTIMATE SEC.
	10.08.88	CN CK. POP. ESTIMATE SEC.
I001230	8.08.88	CN CK. POP. ESTIMATE SEC.
	10.08.88	CN CK. POP. ESTIMATE SEC.
I001231	8.08.88	CN CK. POP. ESTIMATE SEC.
	10.08.88	CN CK. POP. ESTIMATE SEC.

1001298	16.09.88	9-MILE CK.
	29.09.88	12-MILE CK.
1001426	9.08.87	LIMESTONE R.,NEAR MOUTH OF CN CK.
	26.09.87	9-MILE CK.
	30.08.88	CN CK. MOUTH
1001433	6.09.87	MOOKDANCE CK.
	23.09.87	MOONDANCE CK.
1001439	10.09.87	MOONDANCE CK. ***ALIAS 49-117***
	27.09.87	LIMESTONE R. @ 5-MILE HOLE
1001441	11.09.87	MOONDANCE CK.
	22.09.87	MOONDANCE CK.
1001478	2.10.87	WILSON CK.
	3.10.87	WILSON CK.
	14.10.87	WILSON CK.
1001509	1.08.87	LIMESTONE R.,NEAR MOUTH OF CN CK.
	30.08.88	CN CK. MOUTH
1001510	13.08.87	9-MILE CK. @ MOUTH
	16.10.88	12-MILE CK. 100m U/S FROM FENCE
1001512	17.08.87	9-MILE CK.,15M ABOVE FENCE
	29.08.87	9-MILE CK.
1001515	28.08.87	9-MILE CK. @ MOUTH
	13.09.87	9-MILE CK.
	20.09.87	9-MILE CK.
1001517	28.08.87	9-MILE CK.,10M ABOVE FENCE
	29.08.87	9-MILE CK.
1001519	9.09.87	9-MILE CK.,15M ABOVE FENCE
	11.10.87	9-MILE CK.,15M ABOVE FENCE,RELEASED DOWNSTREAM
1001520	10.09.87	12-MILE CK.,10M ABOVE FENCE
	23.09.87	12-MILE CK.
1001524	12.09.87	9-MILE CK.
	8.10.87	9-MILE CK.
1001660	7.09.86	9-MILE CK. SPAWNING POOL
	2.10.87	9-MILE CK.
1001661	7.09.86	LIMESTONE R. @ 5-MILE HOLE
	9.09.86	LIMESTONE R. @ 5-MILE HOLE
1001667	1.06.87	MOONDANCE CK.
	23.06.87	MOONDANCE CK. ABOVE FENCE

I001668	6.06.87	CN CK.
	9.06.87	CN CK.
	19.06.87	CN CK.,50M ABOVE MOUTH
I001669	4.06.87	CN CK.,100M UP FROM MOUTH
	19.06.87	CN CK.,125M UP FROM MOUTH
I001671	5.06.87	MOONDANCE CK.
	4.07.87	MOONDANCE CK.
	23.07.87	MOONDANCE CK. 300M ABOVE FENCE
I001714	27.09.86	WEIR R. SPAWNING POOL
	24.09.88	WEIR R. SPAWNING POOL
	29.09.88	WEIR R. SPAWN POOL ***RETAGGED I001308***
I001774	19.09.88	SKY PILOT CK.
	12.10.88	SKY PILOT CK.
I001826	10.09.87	9-MILE CK. @ MOUTH
	13.09.87	9-MILE CK.
	3.10.87	9-MILE CK.
	5.09.88	9-MILE CK.
I001832	13.09.87	9-MILE CK.
	13.09.87	9-MILE CK.
	2.10.87	9-MILE CK.
I001837	16.09.87	9-MILE CK.
	3.10.87	9-MILE CK.
I001839	20.09.87	9-MILE CK.
	30.09.88	9-MILE CK.
I001843	26.09.87	9-MILE CK.
	2.10.87	9-MILE CK.
	16.10.87	9-MILE CK.
	13.10.88	9-MILE CK.
I001846	27.09.87	9-MILE CK.
	16.09.88	9-MILE CK.
I001850	18.09.87	9-MILE CK.
	2.10.87	9-MILE CK.
I001950	25.09.88	9-MILE CK.
	26.09.88	9-MILE CK.
	28.09.88	9-MILE CK. BESIDE STAFF GAUGE
	1.10.88	9-MILE CK.
OR00456	14.07.85	MOONDANCE CK.
	14.09.87	MOONDANCE CK.
OR00458	14.07.85	MOONDANCE CK.
	9.08.85	MOONDANCE CK. 1KM UP

DR00459	14.07.85	MOONDANCE CK.
	23.05.87	MOONDANCE CK.
	26.05.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 200M ABOVE FENCE
	6.07.87	MOONDANCE CK.
DR00461	14.07.85	MOONDANCE CK. @ MOUTH
	10.08.85	MOONDANCE CK. JUST UP MOUTH
DR00470	17.07.85	MOONDANCE CK. @ MOUTH
	10.08.85	MOONDANCE CK. @ MOUTH
DR00492	16.08.85	9-MILE CK. 1KM UP
	4.09.85	9-MILE CK. 1KM UP
	17.09.85	9-MILE CK. MOUTH
DR00493	16.08.85	9-MILE CK. 1KM UP
	3.09.85	9-MILE CK. 1KM UP
DR00496	16.08.85	9-MILE CK. 1KM UP
	4.09.85	9-MILE CK. 1KM UP
DR00497	16.08.85	9-MILE CK. 1KM UP
	4.09.85	9-MILE CK. 1KM UP
DR00499	16.08.85	9-MILE CK. 1KM UP
	3.09.85	9-MILE CK. 1KM UP
	4.09.85	9-MILE CK. 1KM UP
DR00500	16.08.85	9-MILE CK. 1KM UP
	3.09.85	9-MILE CK. 1KM UP
DR00507	2.09.85	9-MILE CK. MOUTH
	3.09.85	9-MILE CK. MOUTH
	17.09.85	9-MILE CK. MOUTH
DR00508	3.09.85	9-MILE CK. MOUTH
	4.09.85	9-MILE CK. MOUTH
	1.10.86	LIMESTONE R. @ 5-MILE HOLE
	16.08.87	9-MILE CK. R.BEARDY
DR00510	3.09.85	9-MILE CK. MOUTH
	16.09.85	9-MILE CK. MOUTH
	17.09.85	9-MILE CK. MOUTH
DR00511	3.09.85	9-MILE CK. 1KM UPSTREAM
	4.09.85	9-MILE CK. 1KM UPSTREAM
DR00512	3.09.85	9-MILE CK. 1KM UPSTREAM
	4.09.85	9-MILE CK. 1KM UPSTREAM
DR00514	3.09.85	9-MILE CK. 1KM UPSTREAM
	7.09.86	9-MILE CK. SPAWNING POOL
	27.09.87	9-MILE CK.

0R00515	3.09.85	9-MILE CK.1KM UPSTREAM
	4.09.85	9-MILE CK.1KM UPSTREAM
0R00516	3.09.85	9-MILE CK.1KM UPSTREAM
	29.07.87	9-MILE CK.
0R00518	3.09.85	9-MILE CK. MOUTH
	4.09.85	9-MILE CK. MOUTH
	17.09.85	9-MILE CK.@ MOUTH ,RETAGGED #0R00527 ###########
0R00522/23	4.09.85	9-MILE CK.1KM UPSTREAM
	27.09.86	9-MILE CK. SPAWNING POOL
0R00536	7.09.85	LIMESTONE R. 7 MILES UPSTREAM
	17.09.85	9-MILE CK. MOUTH
	17.09.87	9-MILE CK. R.BEARDY (GILLNET)
0R00545	9.09.85	BIRD CK. , BELOW CULVERTS
	1.08.87	LIMESTONE R.,@CN CK.####RETAGGED #I001502 #####
0R00553	9.09.85	LIMESTONE R. JUST BELOW CULVERTS
	14.10.85	LIMESTONE R. @ 5-MILE HOLE
0R00555	9.09.85	LIMESTONE R. IN CULVERTS
	14.10.85	LIMESTONE R. @ 5-MILE HOLE
0R00556	9.09.85	LIMESTONE R. IN CULVERTS
	14.10.85	LIMESTONE R. @ 5-MILE HOLE
0R00558	10.09.85	LIMESTONE R. 1 MILE UP FROM BIRD CK. MOUTH
	12.10.85	LIMESTONE R. @ 5-MILE HOLE
0R00559	10.09.85	LIMESTONE R. BELOW CULVERTS
	14.10.85	LIMESTONE R. @ 5-MILE HOLE
0R00576	19.06.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 200M ABOVE FENCE
0R00577	19.06.87	MOONDANCE CK.
	1.07.87	MOONDANCE CK. 200M ABOVE FENCE
0R00586	23.06.87	MOONDANCE CK. 50M ABOVE FENCE
	3.07.87	MOONDANCE CK.200M ABOVE FENCE
0R00587	23.06.87	MOONDANCE CK. 50M ABOVE FENCE
	23.07.87	MOONDANCE CK.200M ABOVE FENCE
0R00588	23.06.87	MOONDANCE CK.100M ABOVE FENCE
	25.06.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 200M ABOVE FENCE
	30.08.87	MOONDANCE CK.
0R00594	24.06.87	MOONDANCE CK.
	1.07.87	MOONDANCE CK.200M ABOVE FENCE

DR00599	4.07.87	MOONDANCE CK.
	22.07.87	MOONDANCE CK.
DR00600	6.07.87	MOONDANCE CK.
	5.09.87	MOONDANCE CK.
DR00801	14.09.85	SKY PILOT CK. @ AA POOL
	19.09.85	SKY PILOT CK. @ AA POOL
DR00803	1.10.86	LIMESTONE R. @ 5-MILE HOLE
	13.09.87	9-MILE CK. ***RETAGGED 1001828***
DR00808	27.05.87	CN CK.
	19.06.87	CN CK.,125M UP FROM MOUTH
DR00822	22.06.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 200M ABOVE FENCE
	29.08.87	MOONDANCE CK.
	7.09.87	MOONDANCE CK.
DR00823	21.06.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 300M ABOVE FENCE
DR00827	20.08.85	SKY PILOT CK. 800M DOWN FROM AA POOL
	14.09.85	SKY PILOT CK. AA POOL
DR00836	22.08.85	SKY PILOT CK.
	17.09.85	SKY PILOT CK. AA POOL
	22.09.85	SKY PILOT CK. AA POOL
DR00838	22.08.85	SKY PILOT CK. 800M DOWN FROM AA POOL
	17.09.85	SKY PILOT CK. AA POOL
	19.09.85	SKY PILOT CK. AA POOL
DR00851	14.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL
DR00852	14.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL
DR00853	14.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL
DR00885	19.08.85	SKY PILOT CK.800M DOWN FROM AA POOL
	16.09.85	SKY PILOT CK. AA POOL
DR00892	15.08.85	SKY PILOT CK. AA POOL
	24.09.85	SKY PILOT CK. MOUTH RADIO TRANS 48.961******
UMX00572	31.08.87	MOONDANCE CK.
	22.09.87	MOONDANCE CK.
UMX00756	16.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL

UMX00758	16.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL
UMX00760	17.09.85	SKY PILOT CK. AA POOL
	22.09.85	SKY PILOT CK. AA POOL
UMX00771	17.09.85	SKY PILOT CK. AA POOL
	18.09.85	SKY PILOT CK. AA POOL
UMX00773	17.09.85	SKY PILOT CK. AA POOL
	19.09.85	SKY PILOT CK. AA POOL
UMX00775	17.09.85	SKY PILOT CK. AA POOL
	19.09.85	SKY PILOT CK. AA POOL
UMX00812	7.07.87	MOONDANCE CK.100M ABOVE FENCE
	8.09.87	MOONDANCE CK.